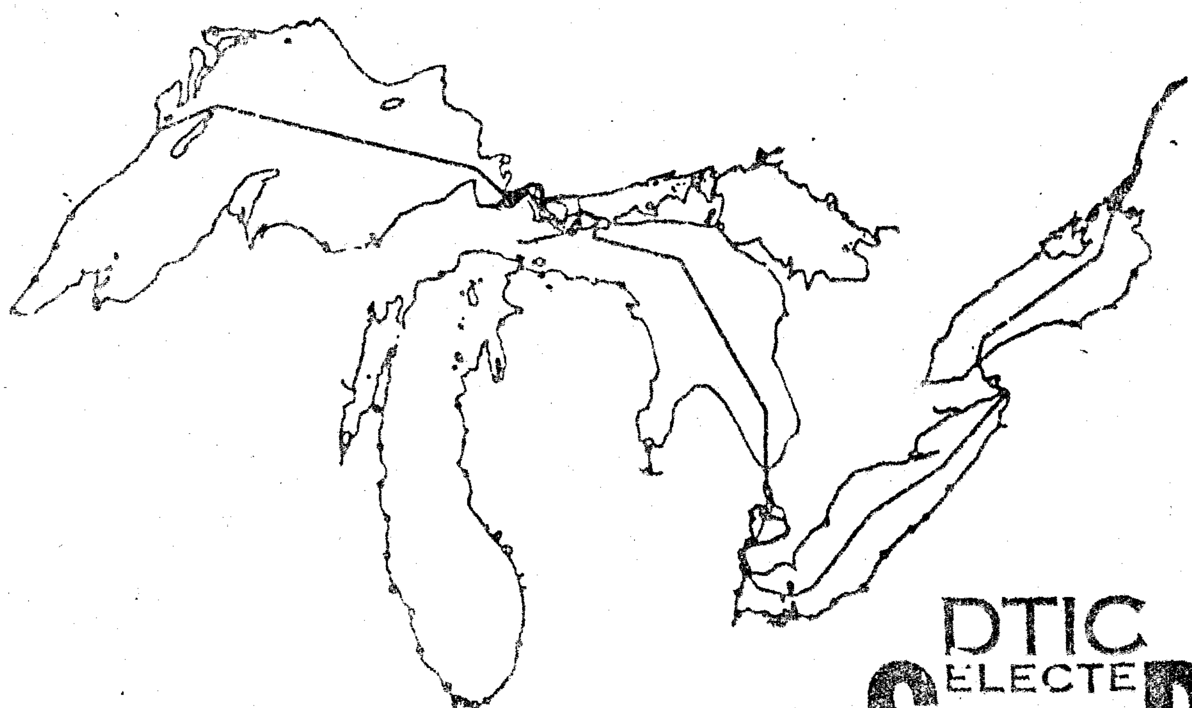
Biological Services Program

FWS/OBS 80/62.2
JUNE 1983

ENVIRONMENTAL BASELINE STUDIES OF THE ST. MARYS RIVER NEAR NEEBISH ISLAND, MICHIGAN, PRIOR TO PROPOSED EXTENSION OF NAVIGATION SEASON, 1981.

Great Lakes-St. Lawrence Seaway Navigation Season Extension Program



Fish and Wildlife Service
U.S. Department of the Interior

Corps of Engineers
U.S. Department of the Army

ENVIRONMENTAL BASELINE STUDIES OF THE ST. MARYS RIVER NEAR NEEBISH ISLAND, MICHIGAN, PRIOR TO PROPOSED EXTENSION OF THE NAVIGATION SEASON

by

Charles Liston, Clarence McNabb, Walter Duffy, Diane Ashton,
Rick Ligman, Fred Koehler, Joe Bohr, Guy Fleischer
Jane Schuette, and Richard Yanusz

Department of Fisheries and Wildlife
East Lansing, Michigan 48824

U.S. Fish and Wildlife Service Contract No. 14-16-0009-79-013

Project Officer - Keith Kraai
U.S. Fish and Wildlife Service
Federal Building
Twin Cities, Minnesota 55111

Funding for this study was provided by
U.S. Army Corps of Engineers
Detroit District Office
Under Agreement No. NCE-IS-80-007

This study was cosponsored by
Department of Fisheries and Wildlife
Michigan State University
and
Michigan Agricultural Experiment Station

Performed for
Office of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior

DISCLAIMER

The opinions, findings, conclusions, or recommendations expressed in this report/product are those of the authors and do not necessarily reflect the view of the Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior, and the Corps of Engineers, U.S. Department of the Army, nor does mention of trade names or commerical products constitute endorsement or recommendation for use by the federal government.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: Unclassified

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE:

3. DISTRIBUTION / AVAILABILITY OF REPORT: Approved for public release; distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S): OBS 80/62.2

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: Michigan State University

6b. OFFICE SYMBOL (If applicable):

6c. ADDRESS (City, State, and ZIP Code): Department of Fisheries and Wildlife, Michigan State Univ East Lansing, MI 48824

7a. NAME OF MONITORING ORGANIZATION: U.S. Fish and Wildlide Service

7b. ADDRESS (City, State, and ZIP Code): Federal Building, Fort Snelling Twin Cities, MN 55111

8a. NAME OF FUNDING / SPONSORING ORGANIZATION: U.S. Army Corps of Engineers

8b. OFFICE SYMBOL (If applicable):

8c. ADDRESS (City, State, and ZIP Code): Detroit District P.O. Box 1027 Detroit, MI 48231

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: NCE-IS-80-007

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification): Environmental Baseline Studies of the St. Marys River Near Neebish Island, Michigan, Prior to Proposed Extension of Navigation Season, 1981

12. PERSONAL AUTHOR(S): Liston, C.R., C.D. McNabb, W. Duffy, D. Ashton, R. Ligman, F. Koehler,

13a. TYPE OF REPORT: Final

13b. TIME COVERED: FROM ________ TO ______

14. DATE OF REPORT (Year, Month, Day): June 1983

15. PAGE COUNT: 350

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Winter Navigation, St. Marys River, Benthic Macroinvertebrates, Aquatic Macrophytes, Ichthyoplankton, Juvenile and Adult Fish.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The objective of this study was to expand existing biological, physical and chemical data for the St. Marys River to monitor possible environmental changes associated with winter navigation-related activities, such as icebreaking and winter ship movements. The field data gathered for this study also supplements data taken during 1979 and 1980. In addition, Lake George, a non-navigated portion, was studied as a potential control site. This report contains data on the following: benthic macroinvertebrates; aquatic macrophytes; ichthyoplankton; juvenile and adult fish; sediment chemistry of shipping vs. non-shipping channels; winter sedimentation rates; and physical and chemical aspects of the water.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL: Thomas Freitag

22b. TELEPHONE (Include Area Code): (313) 226-7590

22c. OFFICE SYMBOL: CENCE-PD-EA

DD Form 1473, JUN 86 Previous editions are obsolete. SECURITY CLASSIFICATION OF THIS PAGE

TABLE OF CONTENTS

12. (cont.) J. Bohr, G. Fleischer, J. Schuette, and R. Yanusz

18. (cont.) Sediment Chemistry, Winter Sedimentation Rates, Physical and Chemical Aspects of Water

Accession For	
NTIS GRA&I	X
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

QUALITY INSPECTED 2

12. (cont.) **J. Bohr, G. Fleischer, J. Schuette, and R. Yanusz**

18. (cont.) **Sediment Chemistry, Winter Sedimentation Rates, Physical and Chemical Aspects of Water**

Page

PREFACE

The general purpose of this study was to expand existing biological and physical/chemical data for the St. Marys River to monitor possible environmental changes associated with winter navigation-related activities (i.e. dredging, ice breaking, winter ship movements). The data may also be used to assess the impacts of an extended navigation season to 31 January ± 2 weeks. Field data were gathered during February through November 1981 to supplement data taken during 1979 and 1980. In addition to sampling within navigated sections of the St. Marys River, a non-navigated portion, Lake George, was studied as a potential control site.

This report contains data on the following topics: benthic macroinvertebrates; aquatic macrophytes; ichthyoplankton; juvenile and adult fish; sediment chemistry of shipping vs. non-shipping channels; winter sedimentation rates; and, physical and chemical aspects of water.

Potential effects of winter navigation activities are of special concern in narrow channel areas of connecting waters of the Great Lakes. Channel areas adjacent Neebish Island on the St. Marys River may be subjected to alteration if winter navigation programs are enacted. An understanding of the biological systems within these waters is necessary for valid impact assessments to be made. The present study increases significantly our knowledge of annual variations in the system, and aids in understanding the biological systems within both shipping and non-shipping stretches of the St. Marys.

During 1981 the environmental monitoring program was extended to include data collections during 1982 and 1983, and was expanded to include several other sites along the river. Many sampling techniques described in this report are now being employed at other channel areas as well as at established stations. New studies involving fish distribution patterns are also now incorporated. In addition, present plans by the U.S. Army Corps of Engineers include an extension of the shipping season to January 31, ± 2 weeks, beginning in 1987. Thus, a significant set of pre-project data involving collections carried out during 1979 to late 1983 will be available as baseline information to help resolve and shed light on potential impacts on the St. Marys River.

This report was submitted in fulfillment of contract number 14-16-0009-79-013 by the Department of Fisheries and Wildlife, Michigan State University, under the sponsorship of the Office of Biological Services, U.S. Fish and Wildlife Service. Funding was provided by the U.S. Army Corps of Engineers, Detroit District Office.

The address of the Information Transfer Specialist for this study is as follows:

Information Transfer Specialist
Office of Biological Services
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, MN 55111

Charles R. Liston, Ph.D.
Associate Professor
Department of Fisheries and Wildlife
Michigan State University
East Lansing, MI 48824

EXECUTIVE SUMMARY

Proposals to extend the Great Lakes commercial shipping season to include winter months have been considered since the 1960's by the United States Army Corps of Engineers. A limited winter shipping program conducted during the 1970's demonstrated that channels and locks could be kept open even during severe winter conditions. Environmental changes resulting from winter navigation activities are of major concern in the narrow connecting waters of the Great Lakes such as the St. Marys River system. Recent proposals for the upper Great Lakes would extend the commercial navigation season to January 31, ± 2 weeks beginning in 1987.

Comprehensive ecological information for the St. Marys River was lacking prior to the late 1970's, and baseline environmental studies on the St. Marys River were begun in 1979 by the Department of Fisheries and Wildlife, Michigan State University, through contract arrangements with the United States Fish and Wildlife Service and Army Corps of Engineers. Studies were extended during 1980 to provide biological information on shallow and deep water habitats to help determine environmental effects of re-distribution of sediments that could result from winter navigation activities. Two comprehensive research reports were completed prior to the present submittal and are available to interested parties.

A second extension of the original studies, reported herein, was granted in early 1981 for the period 1 February 1981 through 31 March 1982. The overall goal of this study was to provide further quantitative and qualitative limnological and biological information from the St. Marys River to help monitor/ assess impacts from winter navigation. Emphasis was placed upon replicating techniques used in earlier studies in near-channel and nearshore environments to observe possible annual variations of existing pre-project conditions. Also, a new environment, Lake George, was studied simultaneously with other sites on the St. Marys to examine ecological conditions in a non-shipping channel as well as in shipping channels. A further expansion of studies was contracted beginning in fall, 1981, and those studies are now on-going and are expected to continue through 1983, with 1984 being a write-up year.

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate sampling was aimed at two objectives. The first was to determine the extent of annual variation exhibited by the benthos at a specific site. Sampling methods employed in 1979 were replicated at Navigation

Courses 7 and 9 during 1981 including sampling apparatus (PONAR grab), replication (60 samples), and time of sampling (June and September).

The second objective was to compare the fauna inhabiting part of the river presently used for navigation with a similar environment not used for commercial navigation. Sampling was conducted *bimonthly from* April through December in Lake George and Navigation Course 5 (Lake Nicolet). On each of five sampling dates triplicate PONAR grab samples were collected from the three meter depth zone while triplicate Ekman grab and Gerking samples were collected from within the vegetated littoral zone of each area.

Abundance of invertebrates from Navigation Courses 7 and 9 ranged from $2{,}016/m^2$ to $22{,}340/m^2$ outside the navigation channel. Within the navigation channel abundance was significantly less and ranged from 980 to $4{,}186/m^2$. Chironomidae larvae were the predominant taxa comprising 55.5 - 59.9% of the total benthos. In all, 87 taxa were identified in samples from these two navigation courses. In addition to Chironomidae, Oligochaeta, Ephemeroptera, Amphipoda, Isopoda, and Trichoptera were considered common.

Abundance of total benthos was greater at all sites in 1981 than 1979. At Navigation Course 7 abundances found in June and September 1981 were 132% and 122% those recorded during the same period in 1979. At Navigation Course 9 total benthos abundance during June 1981 was 235% that found in June 1979. Abundance of total benthos at Course 9 was almost equal during both years in September. Changes in the taxonomic composition of the benthos at Courses 5, 7 and 9 from 1979 to 1981 occurred, but were restricted to genera of Chironomidae.

Average abundance of total benthos at the three meter depth of Course 5 ($13{,}771/m^2$) was greater than that found in Lake George ($9{,}084/m^2$). Within vegetated littoral zones averages of total benthos were similar in Course 5 ($18{,}506/m^2$) and Lake George ($17{,}915/m^2$). While statistically significant, differences among these sites exhibited no consistent pattern.

Eighty-two taxa were found in Course 5 and seventy-five taxa in Lake George; of these, fifty-nine taxa were common to both sites. In Course 5 Chironomidae comprised 55.4% and 57.3% of the benthos at the three meter depth and in the littoral zone, respectively. The second most abundant taxon in Course 5 were Oligochaeta. In Lake George Chironomidae comprised 46.1% of the total benthos at the three meter depth and 44.6% in the vegetated littoral zone. However, the second most abundant taxon was Ephemeroptera. Also, mollusks (pelecypods and gastropods) were more common in Lake George than Course 5.

Estimates of benthic secondary production for 15 common taxa were similar among Course 5 and Lake George when both habitats were considered. Benthic secondary production at the three meter depth and littoral zone of Course 5 was 10,704 and 11,318 $mg/m^2/yr$, respectively. In Lake George secondary production at the three meter depth and in the littoral zone was 16,046 and 6,171 $mg/m^2/yr$, respectively.

AQUATIC MACROPHYTES

The distribution of aquatic plants in Navigation Course 5 of the Upbound Neebish Channel and in Lake George was mapped. Dominant emergent species were Scirpus acutus (hard stem bulrush) and Scirpus americanus (three square bulrush). The time of year when stands reached maximum biomass appeared temperature dependent. On a site protected from circulation of cold channel water into the warmer shore zone, maximum biomass was present from 15 July into September. On a site exposed to circulation of cold channel water, maximum biomass was not present until after 20 August. At maturity, S. acutus and S. americanus biomass was 540 and 272 g ash-free dry weight m^{-2}, respectively. The charophytes (Nitella flexilis and Chara globularis), and Isoetes riparia (quillwort) dominated submersed vegetation. Beds of these plants tended toward constant growing season biomass. Dead or dying tissue of the previous growing season appeared to be sloughed at a rate approximately equal to the rate of replacement of biomass by new growth. In August - September, beds of these plants consisted of new growth. Biomass at that time was 50 - 70 g ash-free dry weight m^{-2}. Differences between transects in Lake Nicolet and Lake George in regard to species, their distributions, and biomass could not be documented by this study. However, the water of Lake George was warmer and thus provided a contrast for evaluating temperature control on growth and development of maximum annual biomass.

Hand sampling techniques were developed for obtaining biomass in submersed plant beds. Thirty samples were taken from beds of Nitella flexilis and Isoetes riparia by hand and by PONAR dredge. A standard procedure was established for converting data obtained by PONAR dredge to hand-sampled equivalents.

Beds of submersed plants at the edge of the Upbound Neebish Channel in 1979 were sampled randomly with the procedures of 1979. Beds occurred in the same locations in 1981. The same species dominated beds in both years and biomass within beds was similar in these years.

Impacts from an extended shipping season (to January 31 by 1987) on aquatic plants are expected to result mainly from scouring over-wintering rootstock systems by ice movement and under-ice pressure waves created by passing ships in narrow channel passages. Any substantial, sustained increases in suspended silt could also change the quantity and quality of light penetrating the water which would be critical during the growing season. Studies being carried out in 1982 and 1983 are documenting the existing extent and substrate biomass of rootstock systems of emergent plants at numerous sites along the river. Further, precise mapping of beds of emergent plants through modern aerial photography is producing extensive baseline data on stands of emergent macrophytes.

ICHTHYOPLANKTON

Larvae of 20 taxa were collected from stations in Navigation Courses 5, 7 and 9, and Lake George in the St. Marys River in 1981. A total of 8,599 larvae were present in 378 samples. Biweekly collections were made at three different depths at each station from April through September. A pull net was used to

sample the shallow littoral zone, generally less than 0.5 m deep. The 0.5 m push net was used in the 1 - 2 m deep region along the edge of the emergent macrophyte beds, while the 1.0 m net sampled the deeper channel stations.

Seasonal trends of appearance and abundance of larvae followed those seen in 1979 and 1980. The majority (57.1%) of the larvae collected were rainbow smelt. Sucker, cyprinid and burbut larvae were also abundant, accounting for 6.9, 10.3 and 5.1% of the catch, respectively. As a group, percid larvae (yellow perch, logperch, and darters) accounted for 13.8% of the total catch in 1981.

Efforts to locate areas of concentration of coregonid larvae showed that, of the stations sampled, nearshore areas in Course 5 yielded the highest densities of cisco and lake whitefish larvae, 50 and 238/100 m^3, respectively. Overall, larvae were most abundant at Station 9, yielding peak densities of larvae (1,559/100 m^3) along the edge of the macrophyte beds in early June, and peak densities (4,487/100 m^3) in the shallow littoral in early July.

Comparison of data from Lake Nicolet and Lake George indicated that the composition of the channel ichthyoplankton among the two areas was similar, being dominated by rainbow smelt. Nearshore collections in Lake George were dominated by cyprinid larvae whereas Lake Nicolet was dominated by percid larvae. The sampling program of 1981 provides some of the first quantitative estimates of density of larvae in a shallow littoral area, and is vital to the assessment and description of nursery areas.

The differences seen among stations in composition and abundance of larval fish reflect utilization of a mosaic of habitats by fish for nursery areas within the river system. All habitats may not contribute the same amount to the recruitment of individual populations. The alterations, if any, imposed by navigation activities would be expected to affect larval fish populations through effects on the littoral zone, namely through loss of habitat in the form of submersed and emergent macrophytes and subsequent food availability and cover they provide. In addition, lateral transport of larvae along the littoral zone during the drawdown and surge action of the water during vessel passage has an effect on survival of larval fish. These impacts remain speculative, however.

JUVENILE AND ADULT FISH

Bottom Gill Nets

Experimental bottom gill nets were employed during 1981 to gather baseline data on species composition, indices of abundance (catch per effort) and lengths of juvenile and adult fishes. Collections were taken at shallow and deep sites of Navigation Courses 5, 7 and 9, and in a non-shipped area, Lake George. Comparisons were made among depths, stations, and between years.

During winter, forty-three 24-hour gill net sets collected 310 fish of 12 species in Navigation Courses 5 and 7. Catch per effort was 7.29. White sucker comprised 42.5% of the catch, while cisco contributed 35.5%. Other important species included yellow perch (6.5%), northern pike (4.5%), and burbot (4.5%).

The winter catch per effort increased substantially over the 1980 value as a response to significant increases in catch rate of white sucker and cisco. Length frequency modes for dominant species were roughly similar during winter between years.

A total of 78 net sets during open water seasons in Navigation Courses 5, 7 and 9 captured 1,742 fish of 26 species. Dominant species were white sucker (25.5%), cisco (21.9%), yellow perch (17.2%), northern pike (11.9%), rock bass (7.6%), and walleye (7.6%). Spring samples were dominated by white sucker, northern pike, cisco, and yellow perch. White sucker, northern pike, and yellow perch were frequently captured during summer. Cisco and walleye were occasionally captured in high numbers, primarily during July. Fall sample dominants were white sucker, northern pike, yellow perch, and rock bass. November collections contained significant numbers of cisco. Nearshore nets yielded higher catch per effort values at all stations than those nets set nearest the ship channel.

A total of 28 gill net sets made during open water seasons in Lake George collected 652 fish of 22 species (catch per effort = 23.2). The catch was dominated by white sucker (30.5%), northern pike (21.8%) and yellow perch (20.2%). Northern pike, yellow perch, and white sucker dominated catches in spring, summer and fall. Rock bass and walleye were collected frequently in July. Small catches of pink salmon and cisco were noted in fall. Catch per effort for all species combined was higher in Lake George compared to Lake Nicolet. Cisco, rock bass, and walleye exhibited higher CPE values in Lake Nicolet.

Catch per effort comparisons for 1980 vs. 1981 indicated a general decline in 1981. Cisco evidenced the greatest decline in CPE between years. Percent composition of catch was roughly similar with the order of dominance of white sucker and cisco switched between years.

Direct effects, if any, of channel dredging, ice breaking, and ship passage on juvenile and adult fishes would probably be wrought primarily upon physiological processes (respiration, growth, reproduction, development and maturation). Other effects may include changes in movement patterns, spatial and temporal abundance, alteration of habitats and changes in linkage and structure of the supporting food webs. Effects of winter navigation related activities appear to be transient with the exception of channel dredging which would have a long-term effect by reducing available fish habitat in the Middle Neebish Channel and reducing colonizable substrate for benthic organisms thereby adversely affecting forage densities. However, no dredging is anticipated in the proposed 31 January ± 2 weeks season extension.

Small Mesh Trap Nets

Small mesh trap nets were used to sample fish populations in the upper littoral zone of the St. Marys River. Twelve hour samples were collected both during night and day periods. Seasonal sampling was conducted in emergent vegetation and open areas in Navigation Courses 5, 7 and 9, and in Lake George.

A total of 8,101 fish representing 42 species were taken in 82 trap net collections in Navigation Courses 5, 7 and 9 (CPE = 98.8). Bluegill was the

most abundant species (28.5% of the total catch). Other major species included brown bullhead (13.6%), yellow perch (12.8%), bluntnose minnow (11.3%), and white sucker (7.8%). Species abundance and composition of these collections varied with season, time of day and station.

A total of 11,769 fish of 35 species were taken in 36 trap net collections (CPE = 326.9) in Lake George. Spottail shiner was the most abundant species (51.5% of total catch). Other major species included common shiner (25.0%), yellow perch (6.6%), bluntnose minnow (3.3%) and black crappie (2.3%). Species composition of collections in Lake George varied with season and time of day.

Numbers of fish sampled in Lake George were greater than numbers taken from other areas. A comparable navigated area (Navigation Course 5) contained fewer fish (CPE = 68.7) than Lake George (CPE = 326.9). Of the sport fishes, yellow perch, smallmouth bass, largemouth bass, northern pike and white sucker were more abundant in Lake George while brown bullhead and bluegill were more abundant in Navigation Course 5. Forage fish also had larger populations in Lake George than Navigation Course 5.

Potential impacts of the proposed commercial shipping season extension remain speculative. Turbulence under ice cover from passing vessels may injure fish or disrupt normal behavior. Increases in suspended solids may also impair normal feeding behavior. The emergent vegetation of the upper littoral zone is important to juvenile fish populations and ice scouring of over-wintering rootstock systems of macrophytes would reduce preferred habitat.

Trawls

Bottom trawl samples were collected at night in nearshore (1.5 m) and offshore (3.1 m) sites within Navigation Courses 5, 7 and 9, and in a non-shipping area, Lake George. A total of 10 samples were taken at each station during May through October. Comparisons were made among depths, stations and between years.

A total of 5,997 fish of 28 species were collected in 30 trawl samples from Navigation Courses 5, 7 and 9. Johnny darters were most abundant, comprising 19.3% of the total catch. Other numerically important species included ninespine stickleback (12.3%), trout-perch (11.8%), yellow perch (9.2%), spottail shiner (7.1%) and mottled sculpin (6.4%). Total catch per effort at Course 5 was approximately half that at either Course 7 or 9. Overall catch in the offshore areas was greater than in the nearshore areas at Courses 7 and 9, but the opposite was true in Course 5. Depth distribution of individual species varied from station to station and by date.

A total of 3,234 fish representing 23 species were collected in 10 trawl samples from Lake George. Trout-perch were most abundant, making up 36.2% of the total catch followed by spottail shiner (19.1%), yellow perch (15.6%), johnny darter (10%) and common shiner (4.4%). White sucker made up only 3.8% of the catch by number but represented nearly 44% of the catch by weight. Overall, more specimens were taken in the deep near-channel area compared to the shallow nearshore area of Lake George. Trout-perch were consistently captured in greatest numbers at the deep station, while johnny darters, Iowa

darters, yellow perch and rock bass were more abundant nearshore. Brook stickleback occurred only in the shallow samples.

The fish community represented by the trawl samples was more diverse in Lake George as compared to Course 5, and overall CPE in Lake George was more than three times greater than at Course 5. Trout-perch, johnny darters, spottail shiners, white suckers, yellow perch, smelt, Iowa darter, brook stickleback, bluntnose minnows and common shiners were much more abundant in Lake George. Rock bass, slimy sculpins, brown bullheads and mimic shiners were each at least twice as abundant in samples from Course 5 as compared to Lake George.

Overall CPE decreased by about 10% from 1980 to 1981 in Courses 7 and 9. Catch per effort of smelt, ninespine sticklebacks and logperch increased significantly from 1980 to 1981. While other species exhibited sometimes drastic changes in CPE, these changes were not statistically significant due to variability of the data. Relative abundances of the major species shifted noticeably from 1980 to 1981. The community was dominated by trout-perch, spottail shiners and johnny darters in 1980, and together the three species made up over 60% of the total catch. In 1981 the order of importance changed to johnny darters, ninespine stickleback, yellow perch and trout-perch, respectively, and these species comprised 56% of the total number caught.

All species sampled by trawls are either spring or summer spawners and there would be little danger of direct egg destruction from winter shipping. Problems associated with winter shipping could possibly be associated with disruption of submerged and emergent aquatic plant beds which are spawning sites for some of the species. If plant beds with their associated over-wintering root systems were destabilized from winter shipping, increased sedimentation during spring and summer could occur which may affect eggs and larvae.

Any discussion of possible reduction in the fish community should be tempered with considerations of compensation by the populations in question. Decreased reproduction may lead to increased survival of young of successful spawners. Also, reduction of fish production from one area may be off-set by immigration from other sites, if sufficient habitat remains unaffected by winter navigation activities.

PHYSICAL AND CHEMICAL ASPECTS

Water Chemistry, Temperature and Turbidity

Water temperature, dissolved oxygen, turbidity, dissolved solids and pH were measured in conjunction with biological sampling in nearshore and offshore sites of Navigation Courses 5, 7 and 9, and Lake George.

Water temperatures were near $0^{\circ}C$ during winter, began increasing in May, and reached maximum values of 19 - $24^{\circ}C$ in late summer. Nearshore areas were warmer in spring and summer compared to offshore areas. The reverse was true for fall. Lake George was warmer than other stations during spring and fall.

Dissolved oxygen values ranged from 3.5 - 13.9 ppm. Most readings were >9 ppm. Lowest values occurred during summer at nearshore sites.

Turbidity values ranged from 0.7 - 120 NTU. Turbidities were generally highest during fall, and at nearshore sites. Lake George experienced higher turbidities than all other sites.

Dissolved solids remained fairly constant at all sites, though this parameter exhibited a total range of 22 - 175 ppm. However, only 3 percent of all measurements were outside a range of 50 - 80 ppm.

No major differences in pH values among sites occurred. Summer offshore pH readings indicated basic conditions while fall offshore readings indicated acidic conditions. A range of 4.8 - 9.2 S.U. occurred, which was larger than that reported in 1980 studies.

The measured parameter most likely to be affected significantly by winter navigation activities would be turbidity because of potential increases in suspended solids carried by the river.

Sedimentation Rates During Winter

Sediment traps were developed and used to collect baseline winter sedimentation data in the St. Marys River to be compared to winter sedimentation data during future commercial shipping and channel modification activities. Lake George, not involved in commercial navigation, was chosen to act as a control.

Samples were collected in off-channel areas of Navigation Courses 5 and 7 and in Lake George during approximately the same period. Trapped sediments were filtered, dryed and weighed over two exposure periods (mid-winter, late winter). Organic/inorganic fractions were determined for sediments collected during the second exposure period.

Sedimentation rates were greater in Lake George (927 - 6,315 $mg/m^2/d$) than in either Course 5 (138 - 592 $mg/m^2/d$) or Course 7 (296 - 592 $mg/m^2/d$) during mid-winter. During late winter sedimentation rates at Courses 5 and 7 increased (296 - 1,342 $mg/m^2/d$). However, sedimentation rates in Lake George (631 - 1,184 $mg/m^2/d$) also averaged more than other areas during late winter. Inorganic content of collected sediments was high, averaging 87.3 - 100% in samples. Turbidity measurements taken during the period indicated a possible positive correlation with sedimentation rates.

Any winter commercial shipping and/or channel modifications that increase the sediment loading in the St. Marys River should be reflected in increased sedimentation in off-channel areas, which, in turn, would be measurable with the sediment traps. However, the site chosen in Lake George as a control does not appear satisfactory with regard to monitoring sedimentation.

Sediment Chemistry of Shipping and Non-Shipping Channels

Sediment cores were collected during June 1981 from an active shipping channel (Lake Nicolet) and an inactive shipping channel (Lake George) and analyzed for 21 parameters including nutrients, heavy metals, organic compounds, total solids, volatile solids and particle size. All parameters except two occurred in higher average concentrations in the shipping channel. According to USEPA Region V criteria, the same parameters exceeded moderate pollution levels at both sites, while those classified as non-polluted were so at both sites, and those below the level of detection also were so at both sites, seeming to indicate shipping was not the source of contaminants in Lake Nicolet sediments.

Lake Nicolet sediments had higher levels of clay and organic matter, and their affinity for heavy metals and organic chemicals may explain the higher concentration of these constituents. Additionally, the higher sedimentation rate in Lake George may bury contaminated sediments reducing the contamination level in the sampled upper sediment layers. These factors, rather than shipping, appear as the most likely reasons for the differences between the two channels. Many other factors, such as redox potential, sediment pH, bacteria, sulfur and iron cycles, not examined in this study, may also strongly affect the levels of materials in sediments.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

AFDW	Ash-free dry weight
C	Celsius, degree
cfs	Cubic feet per second
cm	Centimeter
cm^2	Square centimeter
cm/sec	Centimeter per second
CPE	Catch per unit effort
DW	Dry weight
ft	Foot
g	Gram
g/m^2	Grams per square meter
h	Hour
hp	Horsepower
km	Kilometer
m	Meter
mi	Mile
m/s	Meter per second
m^2	Square meter
m^3	Cubic meter
ml	Milliliter
mm	Millimeter
mg/kg	Milligrams per kilogram
mg/l	Milligrams per liter
No/m^2	Number per square meter
$No/100\ m^3$	Number per 100 cubic meters
NTU	Nephelometric turbidity unit
P	Probability or level of significance
pH	Logarithm of the reciprocal of the concentration of free hydrogen ions
ppm	Parts per million
sp.	Species
S.U.	Standard unit
TL	Total length
$\bar{x}$	Mean, or average
yd^3	Cubic yards
YOY	Young of the year
10^3	Thousand
10^6	Million
μ	Micron or micrometer (one millionth of a meter)
%	Percent
'	Foot
"	Inches

ACKNO LEDGMENTS

This study has required the cooperation of many persons and organizations. The authors were assisted in the gathering and analysis of field data by numerous undergraduate interns of the Department of Fisheries and Wildlife, Michigan State University. We thank Mr. Leo Yeck, Ludington, Michigan, for taking time to counsel us on fishing gear and for net maintenance.

The aquatic macrophyte research was conducted by personnel from the Limnological Research Laboratory at Michigan State University with the assistance of personnel at Dunbar Research Station. The Department of Forestry at Michigan State University is thanked for facilitating arrangement for use of laboratory and living space at the Dunbar Research Station, Barbeau, Michigan. Mr. Jerry Haarer, Director of the Land Management Office, Michigan State University, is equally acknowledged for his help in securing off-campus work and living quarters.

The valuable suggestions and continued interest of Messrs. Christopher Shafer and Asa Wright of the Michigan Department of Natural Resources are appreciated. Mr. Walter Mikula, MDNR Area Law Enforcement Officer, is acknowledged for fielding many questions from citizens.

Dr. Niles Kevern, Chairman, Department of Fisheries and Wildlife, Michigan State University, cooperated with us by providing space and facilities at the MSU campus. Partial staff salaries for this project were contributed by the Michigan Agricultural Experiment Station.

Many thanks are extended to Ms. Barb Poppema for her patience and many hours given to producing nearly flawless typed manuscripts from nearly non-legible handwritten papers.

Mr. Keith Kraai, U.S. Fish and Wildlife Service, has been most understanding and helpful with contract administrative duties. Similarly, we appreciate the administrative assistance, patience and encouragement given by Mr. Les Weigum, Dr. James Galloway and Mr. Mark Fornwall of the Detroit District, U.S. Army Corps of Engineers. Finally, the U.S. Army Corps of Engineers is thanked for the interest displayed in this project and, of most importance, in providing funding.

INTRODUCTION

The St. Marys River is the only outflow of Lake Superior to the lower Great Lakes and flows about 120.7 km (75 mi) from headwaters in Whitefish Bay, Lake Superior to Lake Huron at Detour, Michigan (Figure 1). From its headwaters to Lake Huron the St. Marys River descends approximately 6.7 m (22'). Most of this fall occurs at the St. Marys Rapids and Soo Locks located between Sault Ste. Marie, Michigan and Ontario. Below the Sault Ste. Marie area, the river is divided into several channels and shallow lakes first by Sugar Island and subsequently by Neebish and St. Joseph Islands (Figure 2). The major shipping link between northwestern United States and metropolitan areas in the lower Great Lakes is through the St. Marys River system. During high use years, ship traffic may average over 12,000 vessels with cargos of some 100,000,000 tons per year. Crude oil, petroleum products, grain, steel, coal, taconite and iron ore are the major cargos shipped (Hamdy et al. 1978).

Since 1960, river discharge has averaged about 2,124 m^3/sec (75,000 cfs). A maximum flow of 3,596 m^3/sec (127,000 cfs) was recorded in August 1950, and a minimum flow of 1,161 m^3/sec (41,000 cfs) occurred in September 1955 (International Lake Superior Board of Control 1974). In 1921, complete control of river flow was achieved; under present regulation plans, the minimum flow is controlled at about 1,557 m^3/sec (55,000 cfs).

Plans to extend the commercial shipping season to include winter months on the upper Great Lakes have been seriously considered since the 1960's by the U.S. Army Corps of Engineers, and limited winter shipping through the Soo Locks and St. Marys River was carried out during the 1970's as part of a demonstration program. A successful demonstration program led to proposals for year round shipping on the Great Lakes. More recently, a limited season extension has been proposed which would extend shipping only to January 31, $\pm$ 2 weeks beginning in 1987 (U.S. Army Corps of Engineers, Detroit District, Personal Communication).

The earlier year round shipping season proposals would have required modifications of the St. Marys River, including the dredging and widening of channels near Neebish Island. Michigan State University, Department of Fisheries and Wildlife, first contracted with the U.S. Fish and Wildlife Service in February 1979 to evaluate pre-dredging (baseline) environmental conditions at both the Middle Neebish Channel and at a proposed dredge spoil disposal site in Lake Huron. Extensive background data on physical/chemical aspects, flora, and fauna were gathered during February through November 1979 and were reported in a recent publication (Liston et al. 1980). The objective of that study required intensive sampling restricted mainly to near-channel sites where proposed dredging would directly disturb sediments.

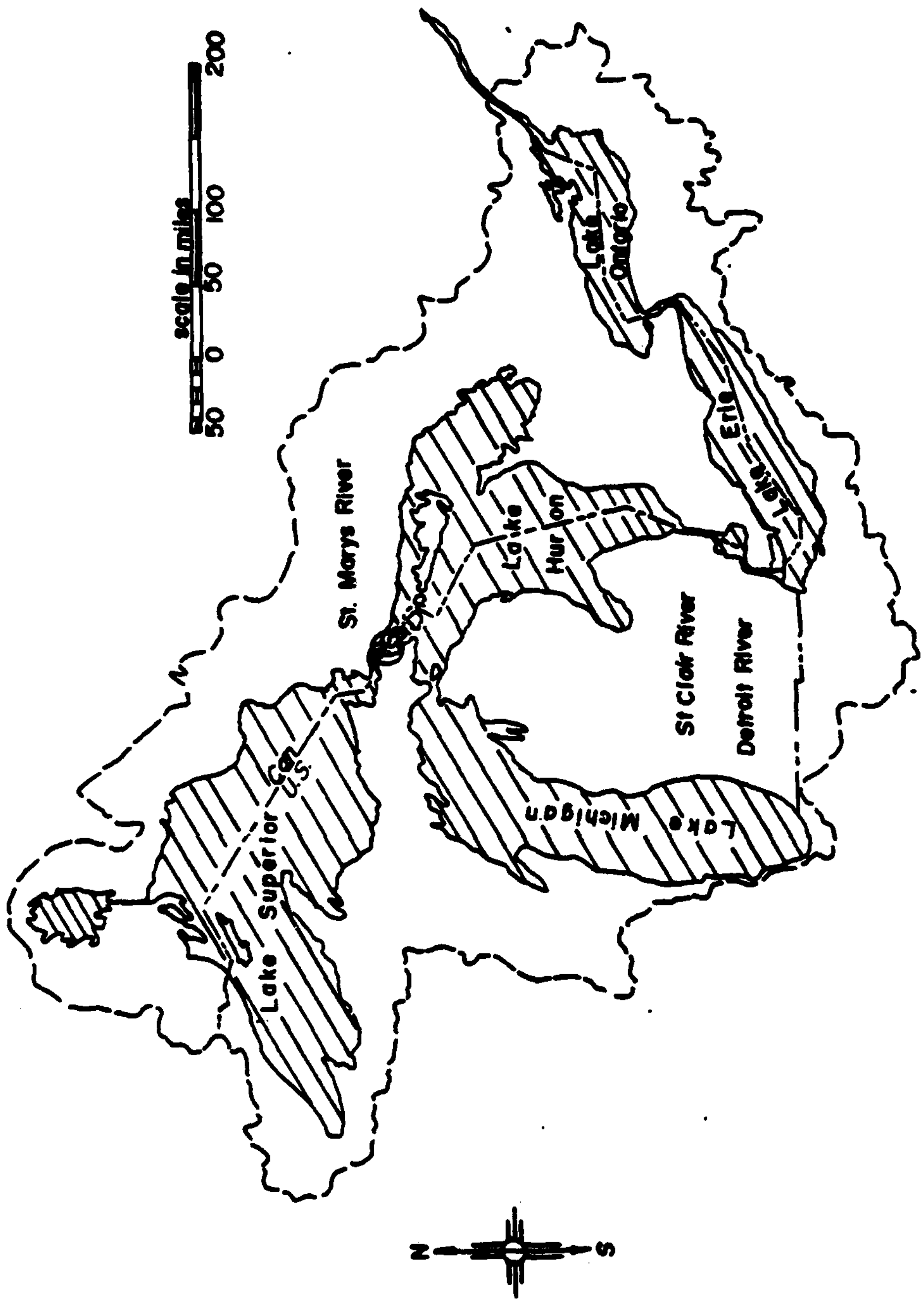


Figure 1. Map of the Great Lakes system showing the general study area on the St. Marys River below Lake Superior.

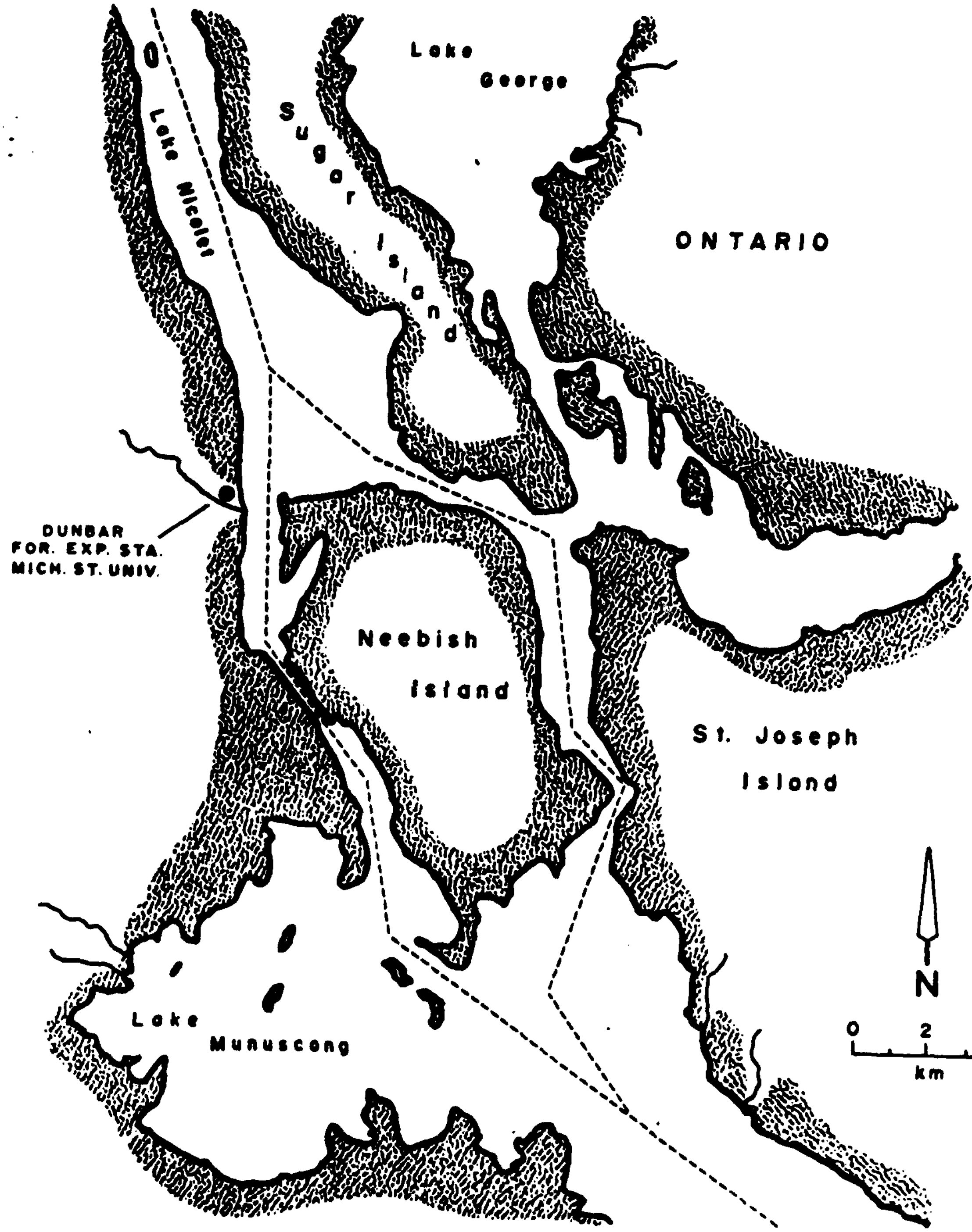


Figure 2. Map of St. Mary's River near the Neebish Island area.

An extension of the 1979 study was granted for the period July through December 1980. The new program was less focused on the channels and sampling was extended into several shallow, off-channel sites. A broader goal was addressed: the baseline data was expanded to aid in determining possible environmental effects of a re-distribution of sediments resulting from winter navigation-related activities (i.e. dredging, ice breaking, ship movements). A report was completed on the 1980 studies and published in 1981 (Liston et al. 1981).

A second extension of the orignial contract, reported herein, was granted in early 1981 for the period 1 February 1981 through 31 March 1982. The overall goal of the on-going study may be stated as follows: to provide quantitative and qualitative limnological and biological information from the St. Marys River to help assess impacts from winter navigation. Emphasis was placed upon continued monitoring by replicating techniques used in earlier studies in near-channel and nearshore environments to observe possible annual variations of existing pre-project conditions. Also, a new environment, Lake George, was studied simultaneously with other sites on the St. Marys to examine ecological conditions in a non-shipping channel as well as in shipping channels. The Lake George area was examined for potential future use as a control site. Throughout the St. Marys studies, data have been gathered during all seasons of the year. Topics covered in this report include: benthic macroinvertebrates; aquatic plants; ichthyoplankton; juvenile and adult fish; water chemistry, temperature and turbidity; winter sedimentation rates; and, sediment chemistry of shipping and non-shipping channels.

During 1981 it was decided by funding agencies that extended research coverage of the large St. Marys River system was important not only for the current monitoring program but also for preparation of environmental impact statements addressing an extended navigation season to 31 January ± 2 weeks by 1987. Consequently, expanded studies were contracted beginning in fall, 1981, and those studies are now on-going and are expected to continue through 1983, with 1984 being a write-up year. The 1984 report will build upon, and will include data submitted in the present report and in the previous two submittals. Techniques successful in past studies are being applied at previously established sites as well as at new sites from above the Soo Locks downriver to near Lime Island. Additionally, new studies dealing with intensive mapping of important plant beds, primary production, and new approaches to identifying adult fish movement patterns have been incorporated.

METHODS AND MATERIALS

BENTHIC MACROINVERTEBRATES

Field Methods

Navigation Courses 7 and 9. Benthic macroinvertebrate samples were collected during June and September, 1981, using a standard PONAR grab which enclosed an area of 484 cm^2 (Wildlife Supply Co., Saginaw, Michigan). Samples were taken along transects across the river at sites where other biological and physical/chemical data were being collected. At each transect, triplicate grabs were taken at 5 stations (Figure 3). One station was located within the navigation channel, one was located 50 m west and another 50 m east of the navigation channel. The two other stations were located in shallow water (1.5 m depth) areas further from the navigation channel with one station each on the east and west sides of the river. A total of 60 PONAR grab samples were collected from these transects during 1981, 15 at each transect during each month.

Navigation Course 5 and Lake George. Two sampling stations were also established in Navigation Course 5 and Lake George (Figure 3). In each area one station was located about 50 m west of the navigation channel in 3 m of water and another was located within the zone of emergent vegetation along the western (lee) shore in 0.5 - 0.7 m of water. Benthic macroinvertebrate samples were collected from each of these stations bimonthly on five dates from April through December, 1981. Sampling at the 3 m depth stations consisted of triplicate PONAR grab samples each date. Sampling within the zone of emergent vegetation consisted of both Ekman grab and modified Gerking samples in triplicate on each date. The Ekman grab encloses an area of 232 cm^2 and is designed to collect organisms in or on the bottom (Wildlife Supply Co., Saginaw, Michigan). The modified Gerking sampler encloses an area of 484 cm^2 and is designed to collect organisms on aquatic macrophytes. This sampler is essentially a plexiglass box with sliding doors attached to the bottom. The top of this plexiglass box is also open and a 149 μ mesh plankton net with a collecting bucket is secured over this opening. In collecting a sample the doors are opened, the sampler lowered over the area to be sampled, the sampler doors are then closed pinching off plant stems, and the sampler is inverted. Contents of the sampler are then rinsed into the collecting bucket. With many of the emergent macrophytes, for example *Scirpus* spp., the stems are too thick to pinch off with the sampler doors and must be cut using a knife. A total of 90 benthic macroinvertebrate samples were collected from Navigation Course 5 and Lake George, 30 with each gear type.

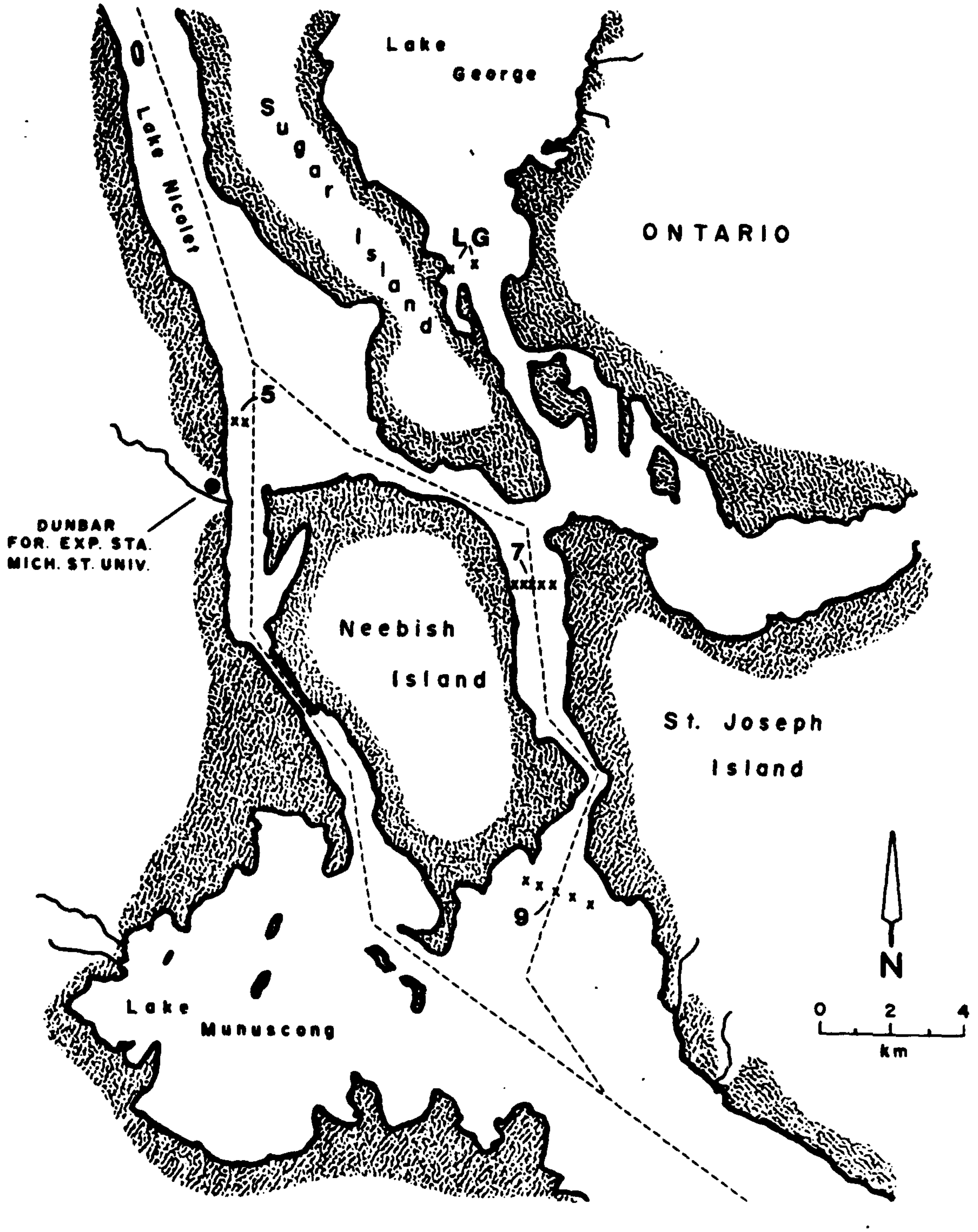


Figure 3. Locations of 1981 benthic macroinvertebrate sampling sites in Navigation Courses 5, 7 and 9, and Lake George, St. Marys River.

Laboratory Methods

Abundance Estimates. All samples were returned to the laboratory in heavy plastic bags and rinsed through a standard No. 30 sieve (600 μ aperture). A 10% subsample of the resultant slurry was then rinsed through a 250 μ and 149 μ sieve. Organisms were sorted from the 600 μ portion of the samples live under 10 X magnification. A stereozoom microscope (magnification 10 - 70 X) was used to sort organisms from the 250 μ and 149 μ portions of the sample. Identification of organisms was accomplished using a stereozoom microscope and a phase contrast compound microscope (100 - 2000 X). Taxonomic references include Bousfield (1958); Burch and Patterson (1976); Edmonds, Jensen and Berner (1976); Heard and Burch (1966); Hilsenhoff (1975); Holsinger (1976); Hungerford (1948); Merritt and Cummins (1978); Pennak (1978) and Williams (1976).

Total benthic macroinvertebrate abundance data was subjected to statistical analysis to determine if observed differences were significant. A Friedman two-way analysis by ranks test was applied to data from Navigation Courses 7 and 9 in testing for differences between years and between seasons (Elliott 1977). Differences in abundance between Navigation Course 5 and Lake George were tested using a 4 X 5 contingency table (Elliott 1977).

Secondary Production. Secondary production was calculated for 15 of the most common macroinvertebrate taxa using the size-frequency method (Hynes and Coleman 1968; Waters and Hokenstrom 1980; Menzie 1981). This method was selected because individual cohorts could not be discerned for all taxa (an assumption implicit in the Allen curve or removal summation methods of calculating productivity). For a review of aquatic secondary productivity techniques see Waters (1977). The terms used in equation for calculating production follow Menzie (1981):

$$P = \sum_{j=1}^{C} (N_j - N_j + 1) \cdot (W_j \cdot W_j + 1)^{1/2}$$

where P is the annual production in $mg/m^2/yr$, W_j is the mean weight of an individual at size j, C is the number of size classes in the life cycle, and N_j is the number of individuals that develop into size class j during the year.

Because some taxa were not univoltine, the number of individuals developing into size class j during the year was adjusted by:

$$N_j = \bar{n}_j \frac{Pe}{Pa} \cdot \text{growth period/CPI} \cdot C$$

following Menzie (1981). Here $\bar{n}_j$ is the mean number of individuals in size class j, Pe is the estimated proportion of the life cycle spent in each size class, Pa is the actual proportion of the life cycle spent in a particular size class, growth period is the number of days in the year for which production is being calculated, CPI is the cohort production interval or time from hatching to attaining the largest size class and C is the number of size classes. Lacking laboratory data on growth rates we set Pe/Pa to unity. The growth

period was defined as a full year while the CPI was expressed as proportion of the year (e.g. 0.5 for taxa having two generations per year, 2.0 for taxa having one generation during a two year period, etc.).

Use of the size-frequency method of calculating production requires information on the abundance of each size class and the mean biomass of each size class per sampling date. Total length of common taxa was recorded during the process of identifying organisms for abundance estimates. Abundance data was then examined to determine which taxa occurred regularly and were common enough to enable calculation of production. Specimens of these taxa were later collected, sorted into 1.3 mm size classes, and dryed at 60°C until a constant weight was obtained. Dry weights for these unpreserved organisms were recorded using a Metler Model H10 balance. When an entire size range of unpreserved organisms could not be obtained an entire size range of organisms preserved in 70% isopropyl alcohol were also weighed. Preserved and unpreserved weights for equal size organisms were then compared, a correction factor determined, and all preserved weights adjusted. These data were then used to calculate exponential curves of the form $Y = ae^{bx}$ approximating growth of an individual where: Y = dry weight (mg), x = total length (mm), e = the natural logarithm, and a and b are constants (Cassie 1969). Mean weight at a particular size was then used with abundance of that size class in determining productivity.

For taxa which were infrequently encountered in samples or collected in low numbers production was not estimated. However, dry weights of these organisms were obtained as above. These data along with weights for taxa for which production was calculated were combined to obtain standing crop (biomass present) data for each sampling date.

AQUATIC MACROPHYTES

During 1981, investigations were conducted to improve and expand baseline information regarding distribution and abundance of aquatic vegetation in the St. Marys River. The interval for field work in this study was May - September 1981. Samples were processed through December 1981; data compilation and analyses were conducted through March 1982. The work was organized to achieve five objectives:

1. Obtain estimates of growing season variation in standing crops of dominant emergent and submersed plants so that the time of maximum standing crop for a year was known.

2. Obtain quantitative descriptions of standing crops of dominant emergent and submersed plants along transects adjacent to Navigation Course 5 (Lake Nicolet) and Navigation Course 7 of the Upbound Neebish Channel.

3. Statistically compare the results obtained by sampling submersed plant beds for biomass using PONAR dredge and hand-harvesting techniques.

4. Obtain an estimate of between-year variation in standing crops of submersed plants by duplicating a portion of the 1979 channel-edge study.

5. Compare the aquatic vegetation in a portion of Lake Nicolet with the aquatic vegetation in a portion of Lake George by mapping a transect in Lake George, obtaining plant biomass along it, and comparing the results to transect data taken in Lake Nicolet adjacent to Course 5 (item 2 above).

Emergent and Submersed Plants in Navigation Courses 5 and 7, and in Lake George

Sampling transects were established along Navigation Courses 5 and 7 of the Upbound Neebish Channel, and in the northwest sector of Lake George (Figure 3). They ran outward from the shore to the depth-limit for growth of submersed plants. For transects adjacent to Courses 5 and 7, the depth-limit for growth was in the shipping channel. The Course 5 transect was a perpendicular from the east shore of Lake Nicolet to Channel Marker 76. In Course 7, the transect ran on a perpendicular to the shipping channel, from shore to a point approximately 140 m upstream of Channel Marker 38. The Lake George transect ran lakeward on a perpendicular to the west shore from an area 2200 m north of the navigation marker on Hay Point. At each of these sites, two markers were placed at known distance from one another (80 - 100 m) on a line parallel to the shore. Emergent vegetation was sampled within beds between markers. Submersed vegetation was sampled in the zone of emergent vegetation; it did not constitute significant biomass. Beyond the emergent zone, submersed plant beds were located by divers with SCUBA who swam transects to the outer depth-limit of vegetation. They placed buoys along transects to mark edges of plant beds of different types.

On 20 September 1981, study areas were photographed with equipment and personnel from the Remote Sensing Center at Michigan State University. A Hasselblad 70 mm camera, model 500 ELM, was used for the photography. The camera was mounted in the aircraft with the focal plain horizontal; exposures were made through an opening in the floor of the cabin. Ektachrome 64 professional film was used from elevations of 305 - 1220 m above the River. Distances were scaled from photographs by using known ground distances between shoreline markers.

At each site, a depth profile was obtained through beds of vegetation from shore to the outer edge of submersed plants. In the emergent plant zones, this was done by walking transect lines using a tape measure. Beyond emergent vegetation, depth profiles were obtained from the trace of a recording bathymeter operating from a boat that moved along each transect at constant speed. The position of channel navigation markers and/or buoys at edges of submersed plant beds was recorded on traces. Horizontal scaling of offshore portions of the transects was obtained from photo-scaled distances between channel markers and buoys; these were placed on bathymeter traces. From this work, figures were drawn to show the horizontal and depth distribution of dominant types of vegetation at each site.

Biomass samples were collected from within dominant vegetation types on each transect. Four sampling dates between June and September were used. Shoots of emergent vegetation within 0.25 m^2 quadrats were cut at the sediment surface and removed. Submersed vegetation was sampled by hand using SCUBA, except where diver safety and efficiency dictated against that approach. Deterrents to hand-harvesting submersed plants were low water temperature early in the ice-free season (before June 15), and high current velocities along edges of navigation channels near the outer depth limit for growth (7 m). In cases such as these, sampling was done from a boat using a PONAR dredge. An area of 0.052 m^2 was enclosed by the jaws of this dredge. For hand-harvesting, fine-mesh nylon sacks were made to fit over one end of metal cylinders that were 15 - 20 cm deep. The area enclosed by these cylinders was 0.051 m^2. Cylinders were placed over vegetation in submersed beds; divers passed a hand through a slit in the nylon bags and freed vegetation from the sediments. The nylon bags kept plant material from floating away on currents during sampling.

Ten samples were taken within each vegetation type each time a transect was sampled. Emergent vegetation was dominated by bulrushes (Scirpus acutus and Scirpus americanus). Beds of these plants were divided into inshore and offshore portions of approximately equal length along a transect. This was done to accommodate earlier growth in shallow portions of emergent beds than in deeper portions during initial phases of the sampling program. Vegetation was collected from 10 quadrats in each portion of emergent beds. Plants in samples of emergents were separated by species, except where a large mix of secondary species occurred (inshore on the Lake Nicolet transect). In the last case, species were lumped for measurement; in other cases, number of shoots, mean shoot height, dry weight (DW), and ash-free dry weight (AFDW) were obtained for each sample by species.

Submersed plant samples were washed free of sediment and debris using screens with 3 mm openings. The quillwort, Isoetes riparia, and charophytes dominated submersed plant beds. Collections from beds of I. riparia were separated by species; number and mean plant height were obtained for quillworts in each sample. Dry weight and ash-free dry weight were determined for each species present. The same approach was followed with samples from a bed of Potamogeton robbinsii that occurred on the transect in Lake George. In samples from charophyte beds, charophytes were separated from secondary species. Nitella flexilis dominated the charophyte biomass. In some samples, it was mixed with species of Chara. A visual estimate of the percentage of fresh charophyte volume was recorded for samples to describe this mix when it occurred. Dry weight and ash-free dry weight measurements were made on combined charophytes in samples. Separate determinations of these weights were made for each secondary species that occurred in collections from charophyte beds.

Emergent and submersed plants were dried shortly after collection to prevent tissue deterioration. This work was done at Michigan State University's Dunbar Research Station on the River near Barbeau, Michigan. Dried samples were packaged in aluminum foil envelopes and sent to the Limnological Research Laboratory on the East Lansing campus. Dry weights and ash-free dry weights were measured there using procedures for aquatic vegetation given in Liston et al. (1980).

Hand and PONAR Plant Sampling Comparisons

Because a combination of PONAR dredge and hand sampling methods was used for sampling submersed vegetation in the River, a study was done to obtain a factor for converting biomass from one method to the other should a statistically significant difference occur between means for biomass collected with these methods. Beds of dominant plant types, charophytes and *Isoetes riparia*, were selected in an area east of Course 7 of the Upbound Neebish Channel. Sampling was conducted between Channel Markers 38 and 40. Collections were made 21 - 23 July 1981. Twenty-five samples were taken by dredge and by hand from each bed. Hand collection took material to a depth of 5 - 7 cm in the sediments. Vegetation was washed, dried, and weighed using standard procedures of this study. An F-test was applied to the results to compare variance between methods. Students' t-test was used to examine the similarity between means (Gill 1978).

Annual Variation in Standing Crops of Submersed Plants

During the interval 19 July - 15 August 1979, beds of submersed aquatic vegetation were located along the starboard edge of the Upbound Neebish navigation channel from Nine Mile Point in Lake Nicolet through Course 10 in Lake Munuscong. This was accomplished by sampling on 36 transects that ran perpendicular to the channel from the channel's edge shoreward. Each transect was approximately 100 m long. A boat was moved along these transects, and five evenly spaced samples were obtained using a PONAR dredge. Approximate boundaries of plant beds along the edge of the Upbound Channel were located by this work. Major beds were found in Courses 5, 7 and 9. Species within beds were identified, and their ash-free biomass was determined. On 15 August 1981, data were obtained to test for between-year variation in bed location, species composition, and biomass. Two transects were chosen at random over locations between Channel Markers 70 - 72, 66 - 68, 36 - 38, 30 - 32, 14 - 16, and 12 - 14. For this work, procedures of the 1979 study were duplicated (cf. Liston et al. 1980).

ICHTHYOPLANKTON

Methods and materials for the 1981 ichthyoplankton studies are stressed in this section, though data comparisons with previous years (1979 and 1980) are made in the results section. Methodologies for 1981 were very similar to previous years, and reference should be made to earlier reports (Liston et al. 1979; Liston et al. 1980) for more details of former ichthyoplankton sampling efforts.

Field

Middle Neebish and Lake George Channels. Weekly ichthyoplankton sampling was initiated in April 1981, primarily during the day at Navigation Courses 5, 7 and 9 (Stations 5, 7 and 9) in the Middle Neebish Channel of the St. Marys River, and in Lake George (Figure 4). Weekly night collections at all stations were initiated in May 1981, followed by biweekly sampling from June through September (Table 1).

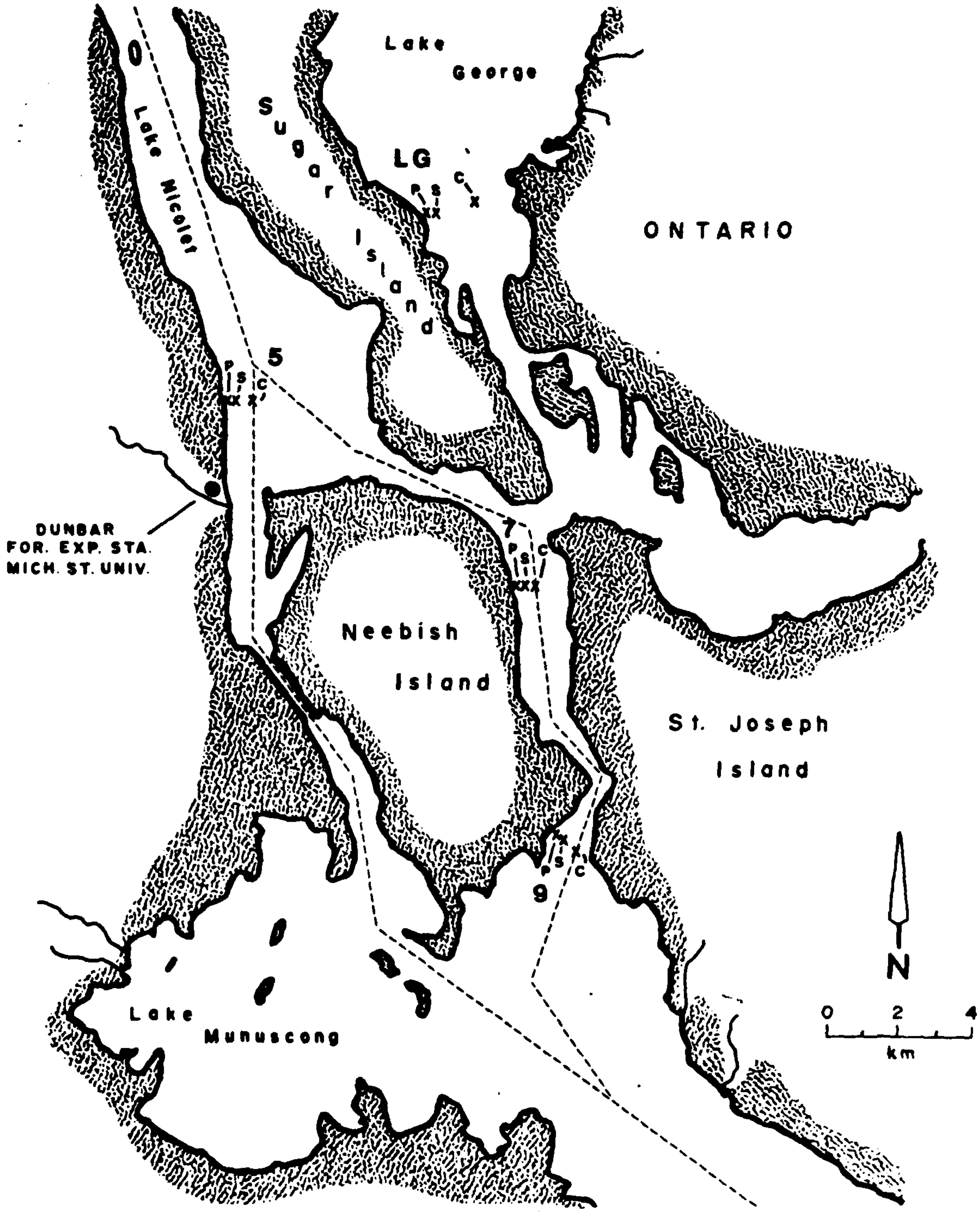


Figure 4. Locations of 1981 ichthyoplankton sampling sites in Navigation Courses 5, 7 and 9, and Lake George, St. Marys River. (P = pull net; S = 0.5 m net; C = 1.0 m net)

Table 1. Schedule of ichthyoplankton sampling in the St. Marys River from April through September, 1981 (Pull net = P; 0.5 m net = S; 1.0 m net = C).

		Station											
		5			7			9			Lake George		
Week	Date	P	S	C	P	S	C	P	S	C	P	S	C
1	4/9-4/10/81	X	X	X	X	X	X	X	X	X	X	X	X
2	4/13/81	X	X	X	X	X	X	X	X	X	X	X	X
	4/17/81	X	X	X	X	X	X	X	X	X	X	X	X
3	4/20/81	X	X	X									
5	5/4-5/5/81	X	X		X	X	X	X	X	X	X	X	X
6	5/14/81	X	X	X	X	X	X	X	X	X	X	X	X
7	5/21/81			X			X			X			X
8	5/26/81	X	X		X	X		X	X		X	X	
10	6/9/81	X	X	X	X	X	X	X	X	X	X	X	X
12	6/23/81	X	X	X	X	X	X	X	X	X	X	X	X
14	7/7/81	X	X	X	X	X	X	X	X	X	X	X	X
16	7/20-7/21/81	X	X	X	X	X	X	X	X	X	X	X	X
18	8/4/81	X	X	X	X	X	X	X	X	X	X	X	X
21	8/24/81	X	X	X	X	X	X	X	X	X	X	X	X
23	9/10/81	X	X	X	X	X	X	X	X	X	X	X	X
26	9/28/81	X	X	X	X	X	X	X	X	X	X	X	X

Samples were collected until early May using a 19 ft Aquasport equipped with dual boom and pulley systems and My-Te winches (Model No. 10-12). Use of the boom system held the nets away from the prop wash of the twin 55 hp outboard engines. Duplicate stepped oblique tows of bridled 1.0 m Nitex conical plankton nets (351 μ) were taken simultaneously in the channel at each station. A General Oceanics digital flowmeter (Model 2030) was mounted in the mouth of each net to estimate the amount of water filtered. A General Oceanics collection bucket was modified by the addition of a rectangular 351 μ mesh patch to the side of the bucket to facilitate concentration of samples (Duncan 1978; Graser 1978).

Each tow was for 5 minutes, with the net being towed for approximately 1 1/2 minutes at each of 3 depths: near the bottom, mid-depth and the surface. A Wildco line/cable clinometer was used to determine the angle of the tow line in order to estimate the towing depth of the sample.

The sampling method was modified after 4 May 1981 due to loss of gear. The tow line was held by hand off the rear of the boat and duplicate stepped oblique tows were taken, though not simultaneously. For bottom and mid-depth tows in the Middle Neebish Channel, 12 and 6 m of line was let out, respectively, and the engine speed maintained such that the towing angle remained between 65 and 75 degrees. In 1979 and 1980, the net was towed off the front of a 16 ft Boston Whaler while backing into the current. For the bottom and mid-depth tows, 18 and 9 m of line, respectively, was let out, and the engine speed maintained such that the towing angle remained between 50 and 65 degrees.

Following completion of the tow, the net was washed down and contents of the collection bucket were preserved in glass quart jars in 10% formalin and returned to the laboratory for sorting and identification.

Concurrent measurements of surface and bottom water temperatures and dissolved oxygen were made at each station. Surface turbidity and pH samples were also collected.

Edge of Macrophytes. A 0.5 m (19.7") 351 μ mesh push net was constructed in 1980 according to the design of Tarplee et al. (1979), and was used to collect ichthyoplankton samples during the day in April and at night for the rest of the field season along the edge of emergent macrophyte beds in both 1980 and 1981. A General Oceanics flowmeter (Model 2030) was mounted in the mouth of the net to estimate the amount of water filtered. A 5-minute tow time was used for each sample collected near macrophyte beds at Stations 5, 7 and 9 and in Lake George (Figure 4). Samples were collected from April through September (Table 1).

Shallow Littoral Zone. A pull net was constructed in April 1980 to collect larval fish in shallow water (less than 70 cm) (27.6") in both open and vegetated areas in 1980 and 1981. The gear is a modified sheet metal snow scoop, commercially available and common in the Sault Ste. Marie, Michigan, area. The back panel was cut out, producing a rectangular mouth area of 1134 cm^2 (21 cm x 54 cm) (8.3" x 21.3"). The 78 cm (30.7") handle was reversed, and a 0.5 m (19.7") 351 μ mesh net was attached to the back of the scoop. A General Oceanics flowmeter (Model 2030) with a low speed rotor was permanently mounted

in the mouth of the net using a small L brace. The gear is pulled through the water by hand. Samples can be collected by one person; however, two people are needed to facilitate both the pulling of the net and subsequent net rinsing and sample handling.

In 1980 and 1981, the pull net was used after ice-out during the day in an effort to collect coregonid larvae in the littoral zone. In 1981, day samples were collected during April, and biweekly pull net samples were collected at night from May through September at Stations 5, 7 and 9 and Lake George (Table 1; Figure 4).

Laboratory

Unstained samples were sorted in the laboratory under 10x magnification either in a black pan, or in a clear pyrex dish on a small light table. Fish eggs and larvae were stored in four-dram vials containing modified Davidson's solution (Lam and Roff 1977).

Identification of fish larvae was made under a Bausch and Lomb binocular microscope fitted with a polarizing filter. Standard length (tip of snout to the end of the notochord or vertebral column, depending on developmental stage) of specimens was measured to the nearest 0.1 mm using an ocular micrometer. A maximum of 20 specimens of each taxon or developmental stage were usually measured. All fish larvae were identified to the lowest taxonomic unit. Complete descriptions of the early life history stages of numerous species are unavailable, hence many specimens could only be identified to genus (e.g., *Etheostoma* sp., or family, e.g., Cyprinidae). Specimens too damaged to permit identification were designated unidentifiable.

Taxonomic references used in the identification of ichthyoplankton included: Cooper (1978a, 1978b), Dorr et al. (1976), Faber (1970), Fish (1932), Hogue et al. (1976), Lam and Roff (1977), Lippson and Moran (1974), Long and Ballard (1976), Mansueti (1964), Mansueti and Hardy (1967), May and Gasaway (1967), Meyer (1970), Nelson (1968) and Norden (1961, 1967). A total of 20 taxa of ichthyoplankton were identified from 1981 samples (Table 2).

Data Presentation

The volume of water filtered during each 0.5 m and 1.0 m net tow was determined by first calculating the distance of the tow:

$$\text{Distance (m)} = \frac{\text{(difference in flowmeter counts)}}{999{,}999} \times \text{rotor constant}$$

where the rotor constant, supplied by the manufacturer, is 26,873 for the standard rotor and 51,020 for the low velocity rotor. The volume is then calculated as follows:

$$\text{Volume (m}^3\text{)} = \text{area of net mount} \times \text{distance}$$

$$= \frac{3.14\ (\text{net diameter})^2}{4} \times \text{distance}$$

Table 2. List of fish larvae collected in pull net, 0.5 m net, and 1.0 m net collections at all stations in the St. Marys River, April through September, 1981.

Scientific Name	Common Name
Clupeidae	Herrings
Alosa pseudoharengus	Alewife
Salmonidae	Salmons, trouts, whitefishes
Coregonus artedii	Cisco
Coregonus clupeaformis	Lake whitefish
Osmeridae	Smelts
Osmerus mordax	Rainbow smelt
Umbridae	Mudminnows
Umbra limi	Central mudminnow
Cyprinidae	Minnows and carps
Cyprinus carpio	Carp
Cyprinidae	Unidentified minnow
Catostomidae	Suckers
Catostomus commersoni	White sucker
Catostomidae	Unidentified sucker
Gadidae	Codfishes
Lota lota	Burbot
Percopsidae	Trout-perches
Percopsis omiscomaycus	Trout-perch
Gasterosteidae	Sticklebacks
Pungitius pungitius	Ninespine stickleback
Centrarchidae	Sunfishes
Ambloplites rupestris	Rock bass
Lepomis sp.	Unidentified sunfish
Percidae	Perches
Etheostoma nigrum	Johnny darter
Perca flavescens	Yellow perch
Percina caprodes	Logperch
Percidae	Unidentified percid
Cottidae	Sculpins
Myoxocephalus quadricornis	Fourhorn sculpin
Cottus sp.	Unidentified sculpin

= 0.7850 X distance (1.0 m net)

= 0.1963 X distance (0.5 m net)

= 0.1134 X distance (pull net)

The volume of water filtered and the number of fish larvae collected were used to estimate the density, or the number of individuals per 100 m^3. Density was calculated by multiplying the number of organisms times 100 and dividing by the volume filtered.

JUVENILE AND ADULT FISH

Gill Nets

Experimental bottom gill nets were employed for seasonal abundance comparison of adult and juvenile fish. Methods and materials for 1981 are stressed in this section, although some data comparisons with previous years (1979, 1980) are made in the results section. Methods for 1981 were very similar to previous years, and reference should be made to earlier reports (Liston et al. 1979; Liston et al. 1980) for greater detail.

Field Sampling. Each experimental bottom gill net consisted of 15.2 x 1.8 m (50' x 6') panels of 25 (1"), 51 (2"), 63 (2½"), 76 (3"), 102 (4"), 114 (4½") and 178 mm (7") stretched mesh nylon of No. 69 twine size (178 mm mesh of 108 twine size). The 106.4 m (350') net consisted of these seven panels.

During February and March 1981, samples were taken in Navigation Course 5 (Lake Nicolet) and Course 7. The nets were set in the morning and retrieved approximately 24 hours later. At Navigation Course 5, sets were made at 4 sites (total of 21) along a northeast transect crossing the downbound channel near buoy number 45 and the upbound channel south of buoys 68 and 69 (Figure 5). A total of 22 sets were made in Course 7, 11 adjacent to the ship channel and 11 nearshore (Figure 5).

During open water (spring, summer and fall), samples were taken in Navigation Courses 5, 7 and 9, and in a non-shipping channel section of Lake George. Nets were set prior to sunset and retrieved after sunrise approximately 12 hours later. With few exceptions, one net was set adjacent the channel and one net was set nearshore each time a station was visited (Figure 5). A total of 107 open water sets were made: 27 in Course 5, 26 in Course 7, 26 in Course 9, and 28 in Lake George.

Analysis of Collections. The total number and weight of each species was recorded from each collection. Fish were released alive whenever possible and length, weight, and sex were recorded when circumstances permitted. The remaining fish were returned to the laboratory where a random sample of 10 to 20 individuals was drawn from each species and total length (mm), weight (g), sex and condition of gonads was recorded for individual fish.

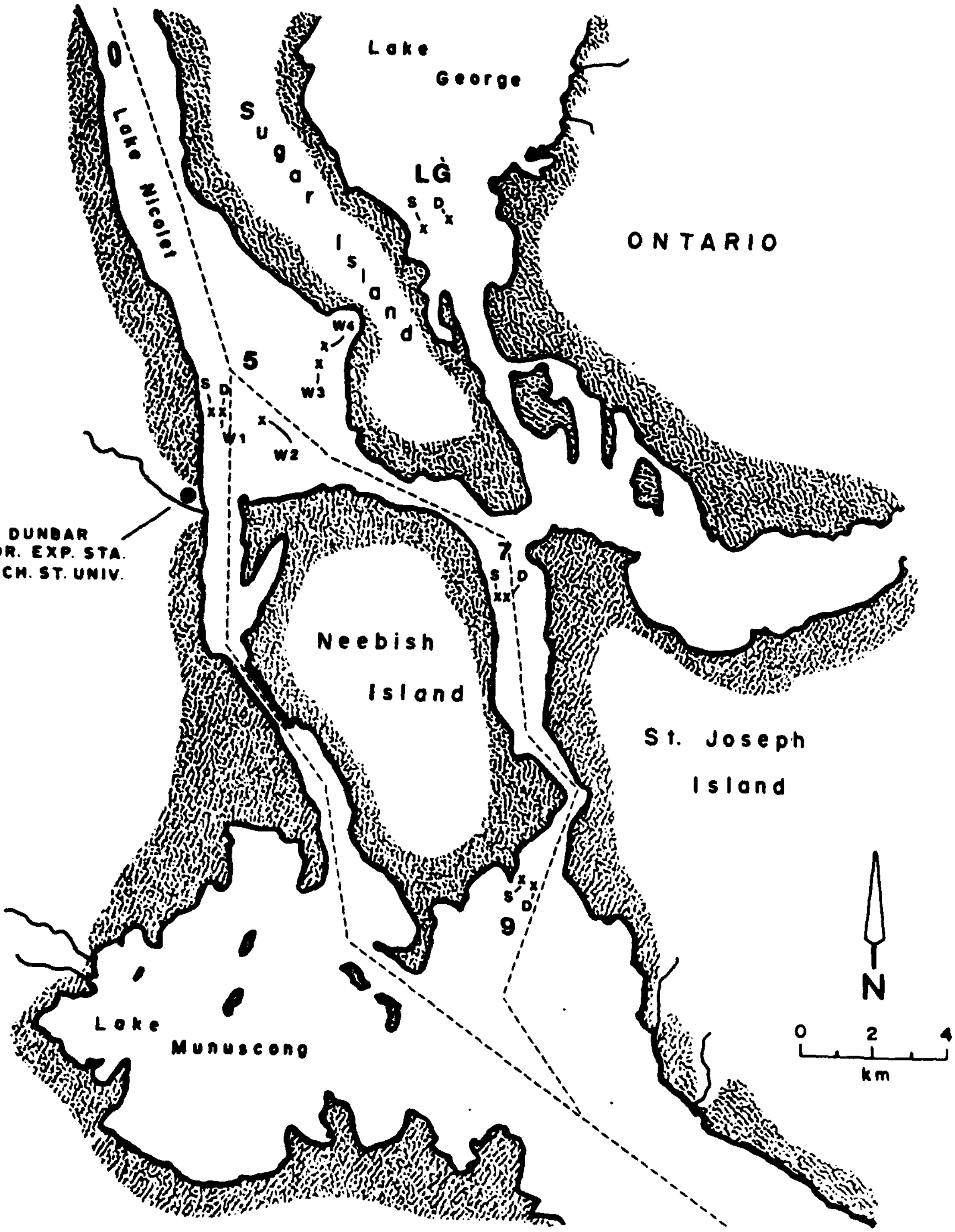


Figure 5. Locations of 1981 gill net sampling sites in Navigation Courses 5, 7 and 9, and Lake George, St. Marys River. (S = nearshore; D = near channel; W1 - W4 = winter sets along Course 5 transect)

Small Mesh Trap Nets

Methods and materials for the 1981 small mesh trap net program are stressed in this section. However, some data comparisons with the previous year are made in the results section. Methodologies for 1981 were similar to 1980, and reference should be made to an earlier report (Liston et al. 1980) for more details of small trap net methods.

Small mesh trap net samples were taken with 6.35 mm (.25") bar mesh nylon nets having a 15.2 x 1 m (50 x 3.3') lead, 2.2 x 1 m (7.2 x 3.3') wings, a 1 m^2 (10.8 ft^2) pot and a single heart. Nets were set in emergent vegetation and open areas of the upper littoral zone (Hutchinson 1967) at each sampling location. A typical sample consisted of setting duplicate nets in the evening, lifting 12 hours later (night sample), resetting and lifting after another 12 hour period (day sample). Thus, a series of four 12-hour samples were taken during a one day period.

Monthly series were taken during May through November at sampling locations in Navigation Courses 5, 7 and 9 (Figure 6). Additional series of samples were taken during August and October in Navigation Course 5 to facilitate comparisons with Lake George collections. Monthly sampling during May through November with additional series in July, August and October was conducted in Lake George (Figure 6).

Fish samples were taken to the laboratory and iced until processed. Processing consisted of recording the total number and total weight of each species captured, and recording length and weight data for individuals. Scale samples were taken when appropriate for later determination of age.

Trawls

Methods and materials for the 1981 trawling program are stressed in this section. However, some data comparisons with the previous year are made in the results section. Methodologies for 1981 were similar to the previous years, and reference should be made to earlier reports (Liston et al. 1979; Liston et al. 1980) for more details of former trawling efforts.

Bottom trawl samples were collected at night with a semi-balloon otter trawl having a 4.9 m (16') head rope, 38 mm (1.5") stretched mesh body and 3 mm (.1") bar mesh cod end liner. Each sample consisted of towing the trawl for 5 minutes behind a 19 ft Aquasport powered by twin 55 horsepower outboard engines.

Fish samples were taken to the laboratory and kept on ice overnight and processed the following morning. Processing consisted of recording the total number and total weight of each species captured, and recording length, weight and sex data for individuals. Scale, otolith or fin ray samples were taken when possible for later determination of age.

Ten trawl samples were collected during May through October from each of Navigation Courses 5, 7 and 9, and Lake George (Figure 7). Samples were taken

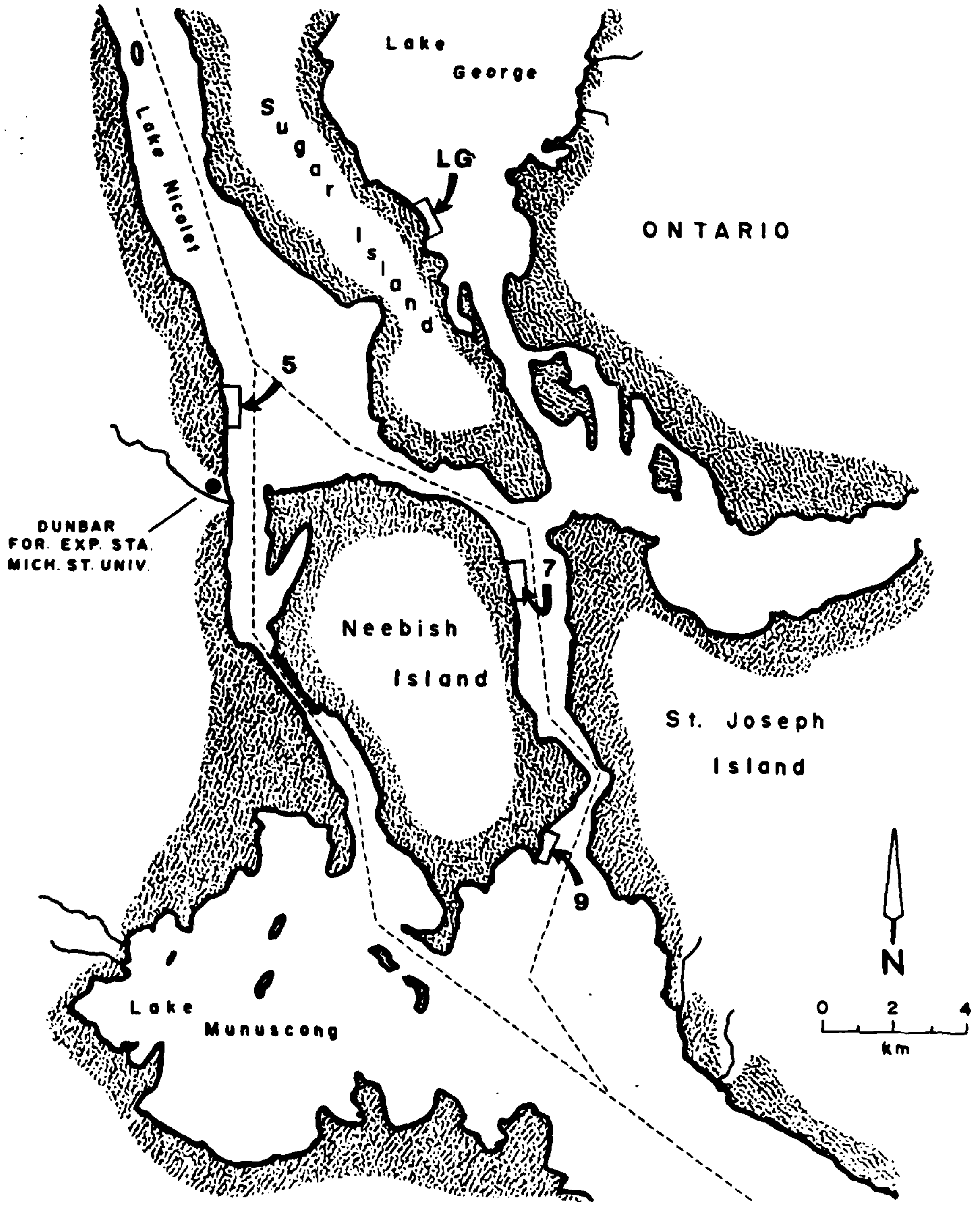


Figure 6. Locations of 1981 small mesh trap net sampling sites in Navigation Courses 5, 7 and 9, and Lake George, St. Marys River.

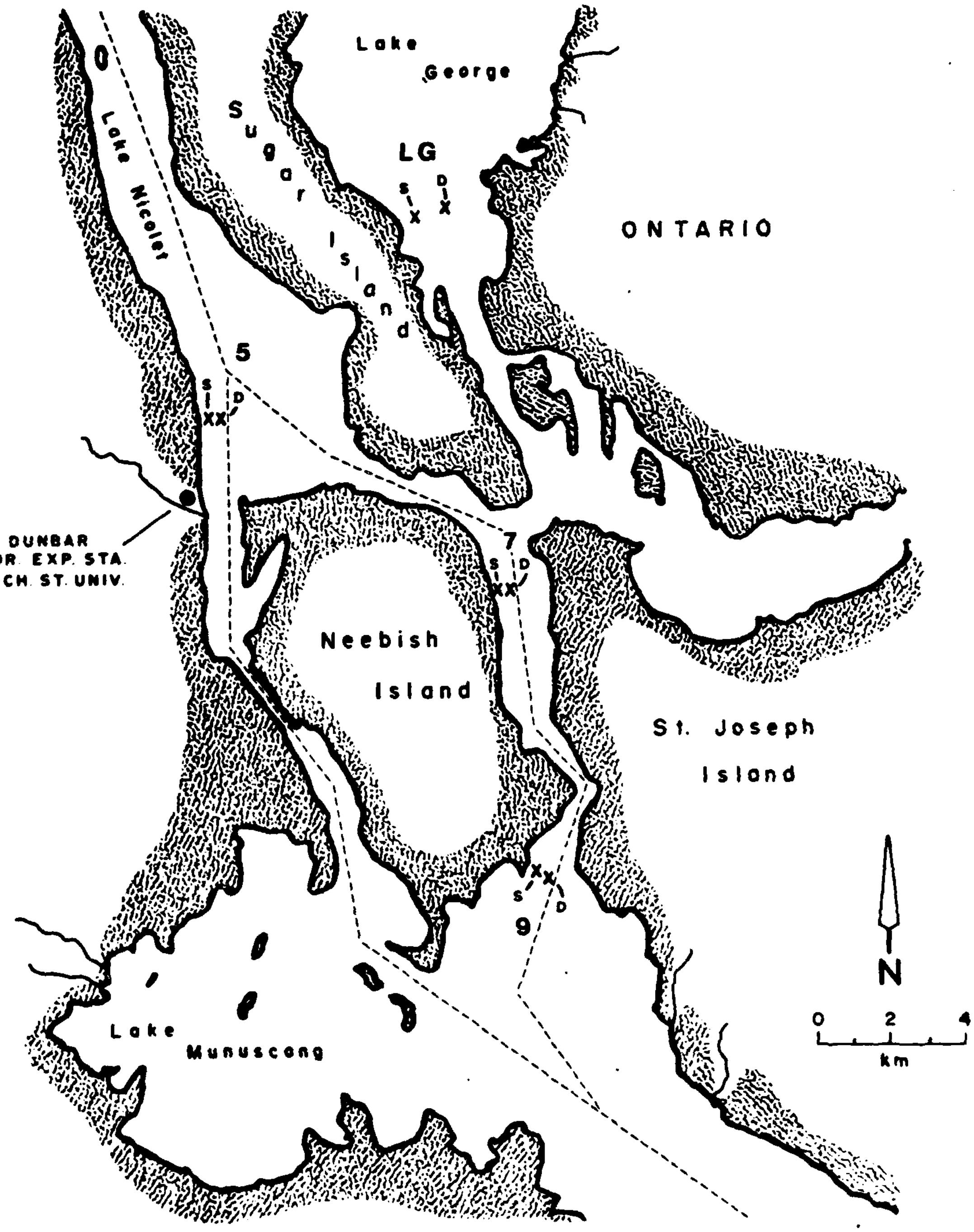


Figure 7. Locations of 1981 trawl sampling sites in Navigation Courses 5, 7 and 9, and Lake George, St. Marys River. (S = 1.5 m depth; D = 3.1 m depth)

at the 1.5 m (5') (nearshore) and 3.1 m (10') (offshore) depth contours of each station on each sampling night.

PHYSICAL AND CHEMICAL ASPECTS

Water Chemistry, Temperature and Turbidity

Physical and chemical parameters were measured in conjunction with biological sampling in Navigation Courses 5, 7 and 9 (Middle Neebish Channel), and Lake George. These included water temperature, dissolved oxygen content, turbidity, dissolved solids content and pH.

Water temperature was measured just below the surface (0.5 m) with a YSI thermister (Yellow Springs Instr. Co., Yellow Springs, Ohio) or with a hand-held thermometer. Dissolved oxygen samples were collected at mid-depth (1 - 2 m) with a 3.5 l capacity Van Dorn bottle (Wildlife Supply Co., Saginaw, Michigan) and analyzed by the azide modification of the Winkler titrametric method. Dissolved solids and turbidity samples were collected just below surface and analyzed with a Myron Model 512T3 dissolved solids meter (Myron Laboratories, Encinitas, California) and Hach Model 2100A turbidimeter (Hach Chemical Co., Ames, Iowa), respectively. Water pH samples, also taken just below surface, were analyzed with either a Markson Model 80 pH meter (Markson Service, Inc., Del Mar, California) or a Hach color comparator.

Physical/chemical data were grouped by depth and by season. Depths were designated as either nearshore (one meter and less deep) or offshore (greater than one meter in depth). The year was classified into seasons as follows: winter, 1 January to 31 March; spring, 1 April to 14 June; summer, 15 June to 31 August; and fall, 1 September to 31 December.

Winter Sedimentation Rates

As part of the on-going studies by the Department of Fisheries and Wildlife at Michigan State University to determine and evaluate possible impacts of proposed winter shipping on the various aquatic aspects of the St. Marys River system, the following investigation was undertaken as a pilot study for the development of a sediment trapping technique and for the collection of baseline winter sedimentation rate data.

The cessation of commercial shipping during the 1980-81 winter season allowed sedimentation rates to be determined in the St. Marys River in the absence of vessel passage (Coast Guard ice-breaker activities occurred, however, and one vessel passage was recorded on March 4 and 5). These data will provide a basis for comparison with the winter sedimentation in the St. Marys River during future commercial winter shipping activities.

Sediment deposition was measured using sediment traps in shallow, off-channel areas of Lake Nicolet and Course 7 (Figure 8). These areas may receive increased sediment deposition by the proposed winter shipping activities. Lake George, not involved in commercial navigation, was chosen as a control (Figure 8).

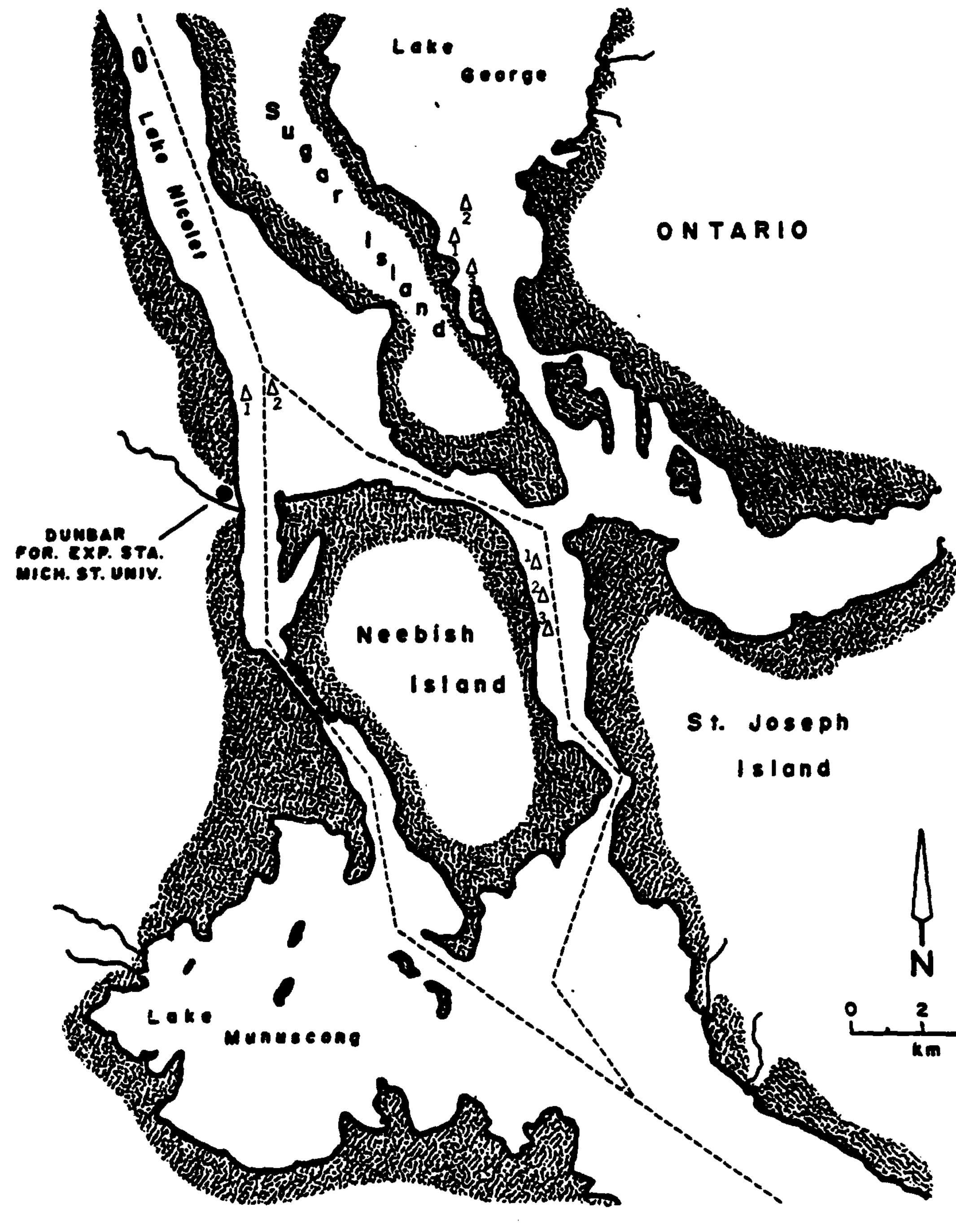


Figure 8. Sediment trap sites in Lake Nicolet, Lake George, and Navigation Course 7 of the St. Marys River during winter, 1981.

A sediment trap, or collector, is designed to measure the downward flux of particles in the water surrounding the trap. Owing to hydrodynamic principles which affect sediment collection, certain design characteristics must be taken into account if the traps are to give a correct measure of the downward flux of particles, especially in flowing water. A major problem in sediment trap design is preventing excess collection of material (Hargrave and Burns 1979). The settling flux of particles in water depends primarily on other factors besides turbulence. But, turbulence can affect the amount of particles trapped if concentration gradients result. Concentration gradients are avoided (i.e. the concentration of particles within the trap is the same as the surrounding concentration in the water) in calm and turbulent waters with simple cylindrical shaped traps (Hargrave and Burns 1979). Once the sediment has settled to the bottom of the trap, it should not be resuspended, or a small area of quiet water should always be present. This requires the cylinders be of ample length so as not to allow turbulence in the lower portion. Therefore, collectors of proper design should be cylinders with a suitable aspect ratio: the ratio of the height to the diameter of the collection tube. The greater the horizontal water velocities encountered, the greater the aspect ratio of the collection tube should be. Collection efficiencies have been shown in laboratory experiments to be near 100 percent in flowing and calm situations for cylindrical sediment collectors with aspect ratios of at least 10 (Hargrave and Burns 1979).

Specifications of Sediment Collectors. The sediment traps were designed and constructed to meet the required specifications for proper trapping efficiency and the physical constraints directed by under-ice application. Each trap consisted of four collection tubes attached with hose clamps to each corner of an iron holding frame (Figure 9). An attachment rod extended from the center of each frame, where a line could be tied for lowering and retrieving the trap.

The collection tubes were 30.5 cm lengths of 2.5 cm inside diameter PVC tubing. This resulted in collection tubes with an aspect ratio of 12. Maximum off-channel current velocities of 26 cm/sec in Course 7 and Lake Nicolet (Liston et al. 1980) were well under the maximum flow velocity in which resuspension begins for an aspect ratio of 12 (Bloesch and Burns 1980).

The folding frames were designed to fit through a 25 cm diameter hole cut by a gasoline-powered ice auger. The resulting outside dimensions of the frame was a 15.2 cm square.

Study Site Placement and Retrieval. A set of three sediment collectors were placed initially at each station: Lake Nicolet on 3 February, Course 7 on 8 February, and Lake George on 5 February 1981 (Figure 8). One from each set was lifted after different exposure times during ice cover. The first series was pulled after 3 to 4 weeks exposure, the second series after approximately 45 days, and the third series left to remain during ice-out and pulled shortly thereafter.

Each station was marked with a long alder branch and the exact position of each site was determined by using a sextant. Three prominant landmarks, usually navigation aides, were chosen and the angles between them measured.

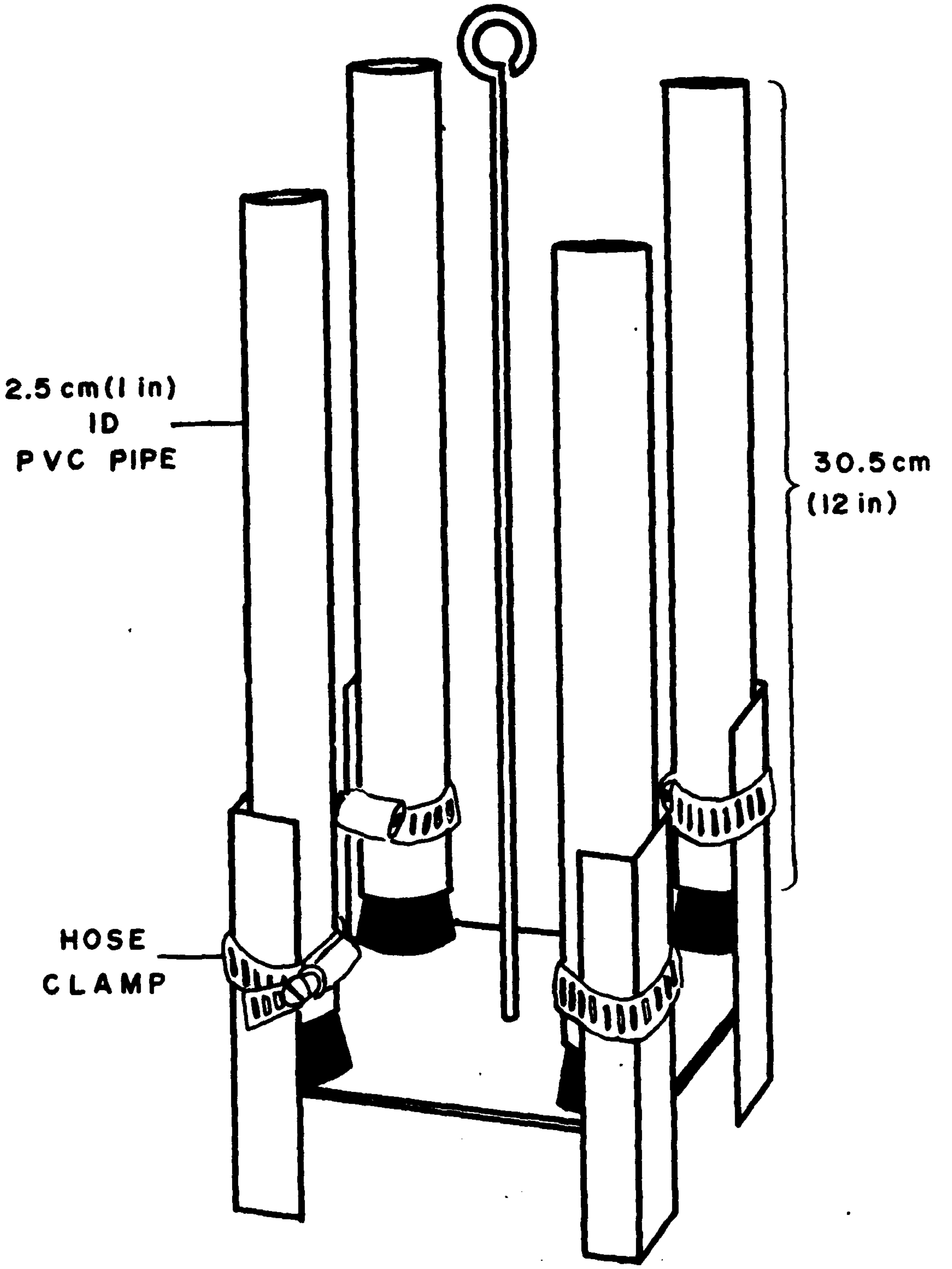


Figure 9. Design and dimension of sediment traps used in the St. Marys River during 1981.

This was done to allow the station to be found after ice-out and for plotting station locations on a map.

Sediment collectors were carefully brought to the surface so as not to disturb the contents. The supernatant water was poured off and the tops sealed with rubber stoppers.

Sediment Analysis. Sediments collected in each trap were removed through the bottom by removing the lower rubber stopper. The collection traps and rubber stopper were rinsed with a wash bottle to remove any remaining sediments. The sediments were filtered through pre-weighed 5 μ pore membrane filters. The filter paper and sediments were dryed at 105° C for at least 24 hours to a constant weight.

Ash-free sediment weights were determined for the second exposure series. These sediments were heated at 550° C for 2 hours and cooled in a dessicator before weighing.

The amount of sediment collected during the first series at each station was subtracted from the amount collected during the second series. This allowed the sedimentation for the second period to be determined at each station. Reported sedimentation rates were determined from the mean sediment accumulation of the four collection tubes on each trap device.

Sediment Chemistry of Shipping and Non-Shipping Channels

The St. Marys River currently experiences heavy seasonal ship traffic between Lakes Superior and Huron with an average of 12,712 vessels carrying some 100,000,000 tons of cargo per year. Crude oil, petroleum products, grain, steel, coal, taconite, and iron ore comprise most of the cargo (Hamdy et al. 1978). Although no extensive water quality problems exist in the St. Marys River, elevated levels of nutrients, heavy metals, and organic compounds have been found in the sediments. Industries and sewage treatment plants near the upper end of the river are sources of contaminants (Liston et al. 1980; Kenaga 1978; Hamdy et al. 1978). However, no investigations regarding the effects of shipping upon the sediment chemistry have been conducted to date. This study will compare the sediment of an active shipping channel with that of an inactive channel, and relate the physical and chemical characteristics of each to natural and anthropogenic influences.

After passing through the Sault Ste. Marie area, the St. Marys River divides into the Lake Nicolet and Lake George channels. The Lake George channel continues east through little Lake George and subsequently turns south, entering Lake George. This channel experienced commercial vessel traffic at one time, but currently is unused. The Lake Nicolet channel proceeds south from its divergence with the main river, passing through Lake Nicolet. This channel is composed of two parallel channels, one upbound and one downbound, with both currently experiencing commercial freighter traffic (Figure 10).

On 18 June 1981, three sites were sampled in Lake George: one in-channel and one each east and west of the channel. Due to the impermeable nature of the substrate, the in-channel sample was actually collected five meters east of the

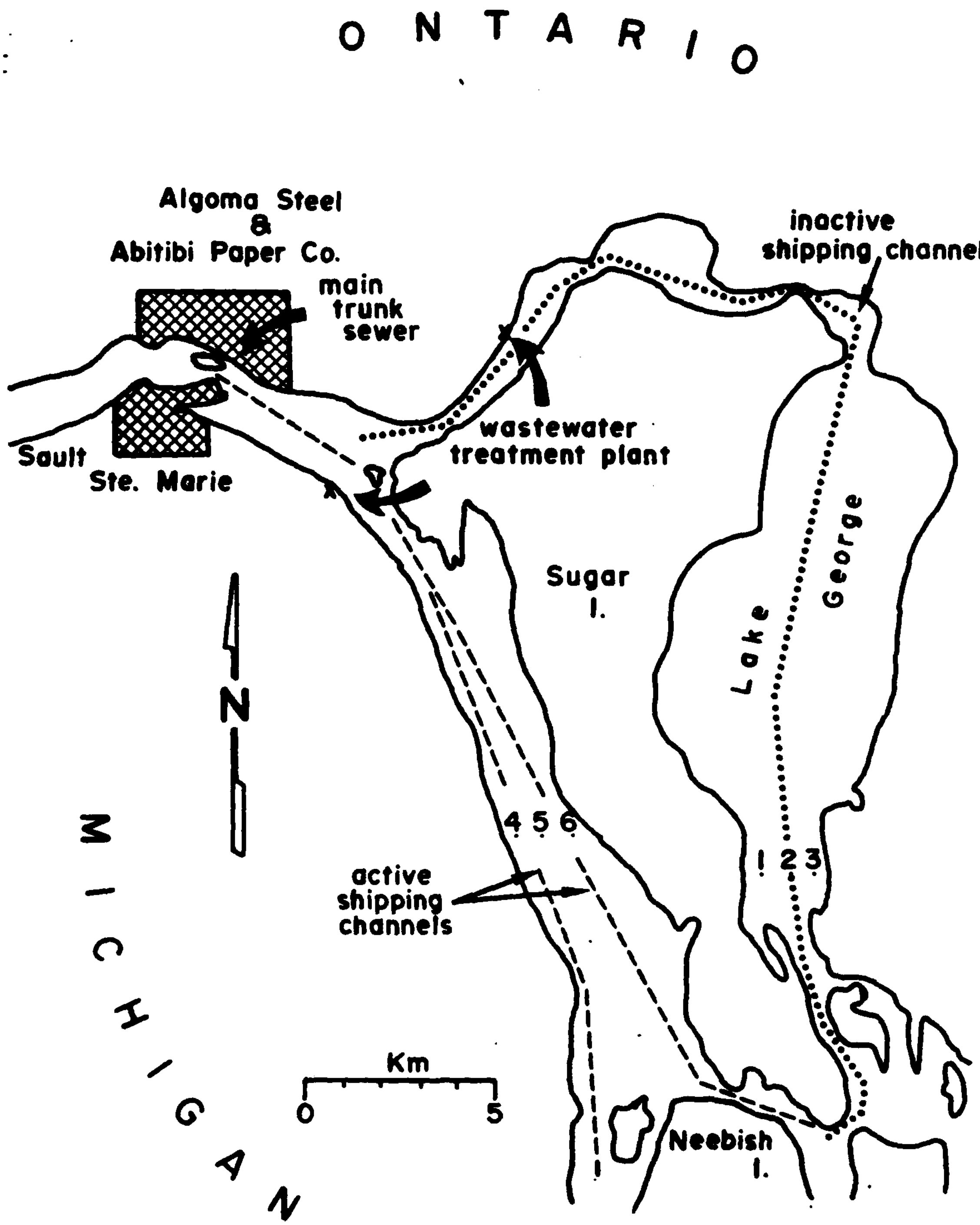


Figure 10. Map of the St. Marys River system above Neebish Island, showing sediment chemistry sampling sites in Lake George and Lake Nicolet.

channel. On 19 June 1981, three sites were sampled in Lake Nicolet: one in-channel and one each east and west of the channel.

Sediment cores were obtained using a 76.2 cm brass coring apparatus with butyrate liners (Wildco Supply Co., Saginaw, Michigan). Depending upon the consistency of the substrate, four to twelve cores were taken at each site and divided between a 1.9 l plastic container for subsequent physical analysis and a 0.95 l glass container for subsequent chemical analysis.

Laboratory analysis of samples was performed by Hydro Research services of Pontiac, Michigan. Methodology conformed to the following manuals: Methods Manual for Bottom Sediment Sample Collection, USEPA, Region V, Great Lakes Surveillance Branch, January 1977; Chemistry Laboratory Manual for Bottom Sediments and Elutriate Testing, USEPA, Surveillance and Analysis Division, Region V, March 1979; Chemistry Laboratory Manual for Bottom Sediments, Great Lakes Region Committee on Analytical Methods, USEPA, December 1969; Methods for Chemical Analysis of Water and Wastes, USEPA, March 1979; and Standard Methods for the Examination of Water and Wastewater, APHA, 14th ed. Parameters measured were total solids, total volatile solids, chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), oil and grease, total cyanide (CN), total phosphorus (P), mercury (Hg), arsenic (As), copper (Cu), total chromium (Cr), lead (Pb), zinc (Zn), iron (Fe), nickel (Ni), manganese (Mn), cadmium (Cd), barium (Ba) and polychlorinated biphenyls (PCB).

RESULTS

BENTHIC MACROINVERTEBRATES

Navigation Courses 7 and 9, 1981

Taxonomic Composition. Eighty-seven taxa of benthic invertebrates were identified from 60 PONAR grab samples collected from Navigation Courses 7 and 9 of the Middle Neebish Channel, St. Marys River during 1981 (Appendix Tables A1 - A4). The majority of these taxa were collected from both navigation courses, however, each course also contained taxa not found at the other.

Chironomidae larvae predominated in samples collected from Course 7 during both June and September comprising 59.9% and 55.8% of the total benthos, respectively (Table A1). Although 19 genera were identified from Course 7 samples, 3 genera comprised almost three-quarters of the June and over half of the September Chironomidae (Table A2). *Polypedilum* sp., *Larsia* sp., and *Cryptochironomus* sp. comprised 37.7%, 19.8% and 16.1% of the Chironomidae, respectively, during June. Other genera which comprised greater than 5% of the June Chironomidae included *Cladotanytarsus* sp. and *Procladius* sp. During September *Polypedilum* sp. and *Larsia* sp. were again predominant, each comprising 21.2% of the total Chironomidae. *Procladius* sp. represented 14.1% of the September Chironomidae, while genera comprising greater than 5% of the total Chironomidae included *Ablabesmyia* sp., *Coelotanypus* sp., and *Tanytarsus* sp.

Five genera of Ephemeroptera were collected from Navigation Course 7 during 1981 including *Ameletus* sp., *Caenis* sp., *Ephemera* sp., *Hexagenia* sp. and *Leptophlebia* sp. The most abundant mayfly collected from Course 7 was *Hexagenia* sp. which comprised 85% and 80% of the mayflies collected in June and September, respectively (Tables A1 and A2). *Ephemera* sp. was also common at Course 7. Both of these burrowing mayflies were more abundant on the west (United States) side of the river. Other genera of Ephemeroptera were less common and more irregular in distribution.

Trichoptera were represented by 10 genera at Course 7. *Polycentropus* sp. comprised 43.2% of the June and 15.4% of the September Trichoptera. Three genera of Leptoceridae (*Mystacides* sp., *Oecetis* sp. and *Trianodes* sp.) together comprised 16.8% of the June and 39.4% of the September Trichoptera. Other genera of Trichoptera were encountered infrequently.

Other taxa which comprised significant portions of the total benthos at Course 7, but were not taxonomically diverse included Ceratopogonidae, the amphipod *Hyalella azteca*, the isopod *Asellus* sp. and Oligochaeta. Oligochaeta

were not identified to the generic or specific level. However, Oligochaeta comprised 21.0% of the June and 16.9% of the September benthos at Course 7.

Mollusks were common in June samples from Course 7, but uncommon in September. Gastropoda comprised 2.0% of the total benthos from Course 7 during June, with Amnicola sp. being the most common genera encountered. Pelecypoda (Sphaerium sp. and Pisidium sp.) were collected in low numbers on the west side of the river during June. Neither genera was numerically common, however.

The taxonomic composition of benthic invertebrates at Navigation Course 9 during 1981 was similar to that found at Course 7, with several exceptions. As at Course 7, Chironomidae were the most abundant taxon comprising 59.9% and 55.5% of the total benthos during spring and fall, respectively (Tables A3 and A4). As at Course 7, Procladius sp., Polypedilum sp. and Larsia sp. were common at Course 9 during June and comprised 31.2%, 14.4% and 10.2% of the total Chironomidae, respectively. In addition, Stictochironomus sp., a genera uncommon at Course 7, comprised 19.4% of the total Chironomidae of Course 9 during June (Table A3). During September Larsia sp., Polypedilum sp., Stictochironomus sp., and Procladius sp. comprised 36.9%, 20.5%, 14.1% and 13.4% of the total Chironomidae, respectively.

Ephemeroptera and Trichoptera collected from Course 9 were roughly similar to Course 7. Hexagenia sp. was the most common ephemeropteran collected from Course 9. However, Ephemerella sp. and Isonychia sp. which appeared in June Course 9 samples were not found at Course 7. Phylocentropus sp., was the most common Trichoptera collected from Course 9 during both June and September (Tables A3 and A4).

Oligochaeta were less common at Course 9 than at Course 7 in June. The amphipod Gammarus sp. was collected from Course 9, but absent from Course 7 and the isopod Lirceus sp. was more common at Course 9 than Course 7. In addition, more genera of mollusks (6 Gastropoda and 3 Pelecypoda) were collected from Course 9 than Course 7.

Abundance. Estimates of mean total macroinvertebrate abundance at Courses 7 and 9 ranged from 2,016 - 22,340/m^2 outside the navigation channel during June and September combined. Within the navigation channel estimated means were 980 - 4,186/m^2. Seasonal mean abundances of total benthos at Course 7 were 11,693.2/m^2 in June and 8,283.2/m^2 in September. Outside the navigation channel seasonal mean abundance of total benthos was 13,570.0/m^2 during June and 10,109.0/m^2 during September. Similarly, at Course 9 seasonal mean abundances of total benthos were 7,337.0/m^2 during June and 9,032.4/m^2 during September. Omitting the navigation channel, seasonal means for Course 9 were 8,847.5/m^2 and 10,688.5/m^2 during June and September, respectively. Differences in total benthic invertebrate abundance among Courses 7 and 9 were not significant ($P > 0.10$, $X^2 = 1.65$, 3df). However, estimates of total benthos abundance within the navigation channel were significantly lower ($P < 0.05$, $X^2 = 10.2$, 4df) than estimates of abundance outside the navigation channel when considering both courses combined.

Annual Comparisons, 1979 vs. 1981

Benthic macroinvertebrate data collected previously allow comparisons of the present 1981 data with 1979 data among three navigation courses, 5, 7 and 9. At two of these sites, Courses 7 and 9, collection methods were identical during 1979 and 1981. However, following 1979 the Navigation Course 7 biological sampling station was relocated northward so as to lie in closer proximity to the 1979 Course 6 station. Because of this comparisons made between years for Course 7 were made between Course 6, 1979, and Course 7, 1981. At Navigation Course 5 one offshore site was sampled on five dates during 1981. Data from June and October of 1981 are compared with the May/June and September data of 1979. However, data from Course 5 were not tested statistically because of the limited replication per date.

Navigation Course 5. Abundance of total benthic invertebrates at the 3 m depth west of the downbound navigation channel was greater in 1981 than in 1979 during both spring and fall. Total benthos during spring 1981 ($15,788/m^2$) was roughly five times that during spring 1979 ($3,100/m^2$). Greater numbers were due primarily to greater numbers of Chironomidae ($1,718/m^2$ in 1979 and $10,633/m^2$ in 1981) and Oligochaeta ($63/m^2$ in 1979 and $1,974/m^2$ in 1981). Amphipoda were also more abundant in spring 1981 ($1,617/m^2$) than 1979 ($594/m^2$).

During fall a similar pattern was noted. Chironomidae were much more abundant in October 1981 samples ($13,418/m^2$) than in September 1979 samples ($2,332/m^2$). Other taxa exhibiting increases of a similar magnitude from fall 1979 to 1981 were Oligochaeta (5,660 vs. $24,280/m^2$), Amphipoda (352 vs. $3,640/m^2$) and Ephemeroptera (104 vs. $1,001/m^2$).

The only shifts in generic importance noted between years was within the Chironomidae. During spring, 1979, the most common genera at Course 5 were Larsia sp., Cricotopus sp., Procladius sp., and Heterotrissocladius sp. During spring, 1981, the most common genera included Polypedilum sp., Cricotopus sp., Larsia sp., and Procladius sp. also in decreasing order of abundance. Heterotrissocladius sp. was not found at Course 5 in spring 1981.

Navigation Course 7. Mean abundance of total benthic invertebrates at Course 7 exhibited a similar pattern among years during both seasons (Figure 11). Lowest densities were consistently found within the navigation channel. Highest densities were more often found in deep water adjacent the navigation channel than in shallow water. Overall transect means of total benthos were slightly greater in 1981 than in 1979. Mean abundances of total benthos during spring and fall 1981 were 11,693 and $8,283/m^2$, while mean abundances during spring and fall, 1979, were 8,801 and $6,748/m^2$, respectively. Differences in total benthic invertebrate abundance among years at Course 7 were not statistically significant ($P > 0.10$, X^2 0.10, 3df = 6.12).

Chironomidae comprised 55.8 - 68.0% of the total benthos at Course 7 between years and seasons. As would be expected Chironomidae had the greatest influence on total benthos abundance data. As with total benthos, patterns in abundance across transects were similar within seasons, with lowest densities occurring in the navigation channel (Figure 12). Greatest increases in

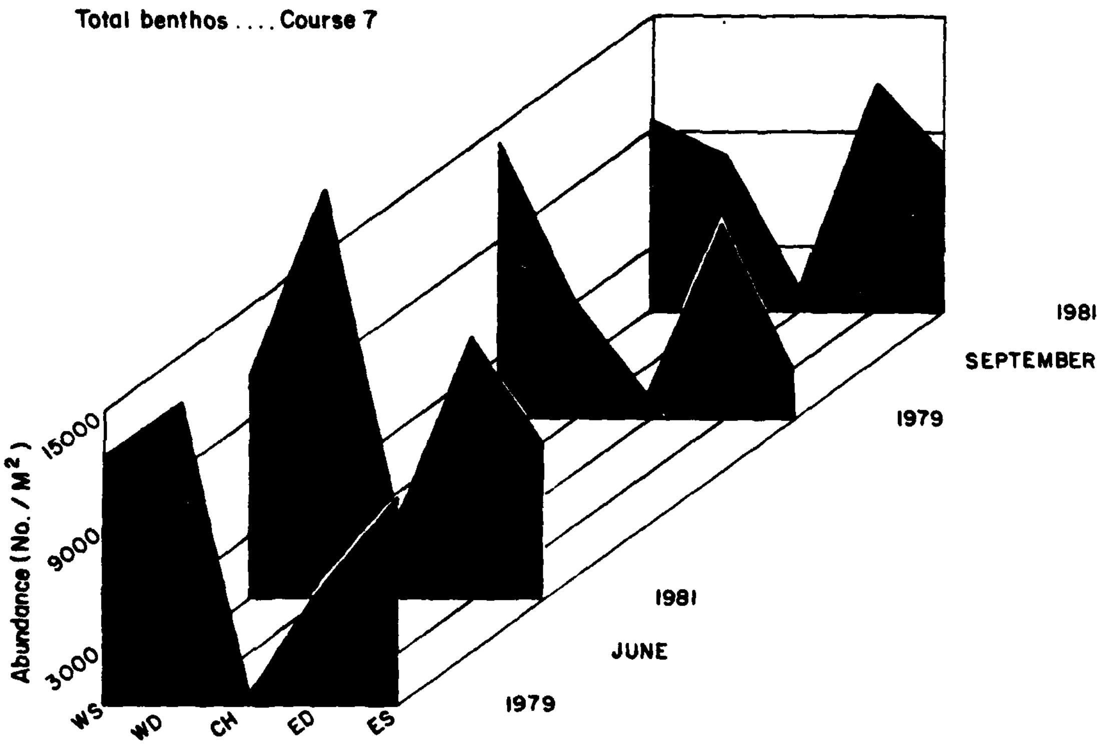


Figure 11. Comparison of 1979 and 1981 total benthos at Navigation Course 7 during June and September, St. Marys River. (WS = west shallow, WD = west deep, CH = channel, ED = east deep, ES = east shallow)

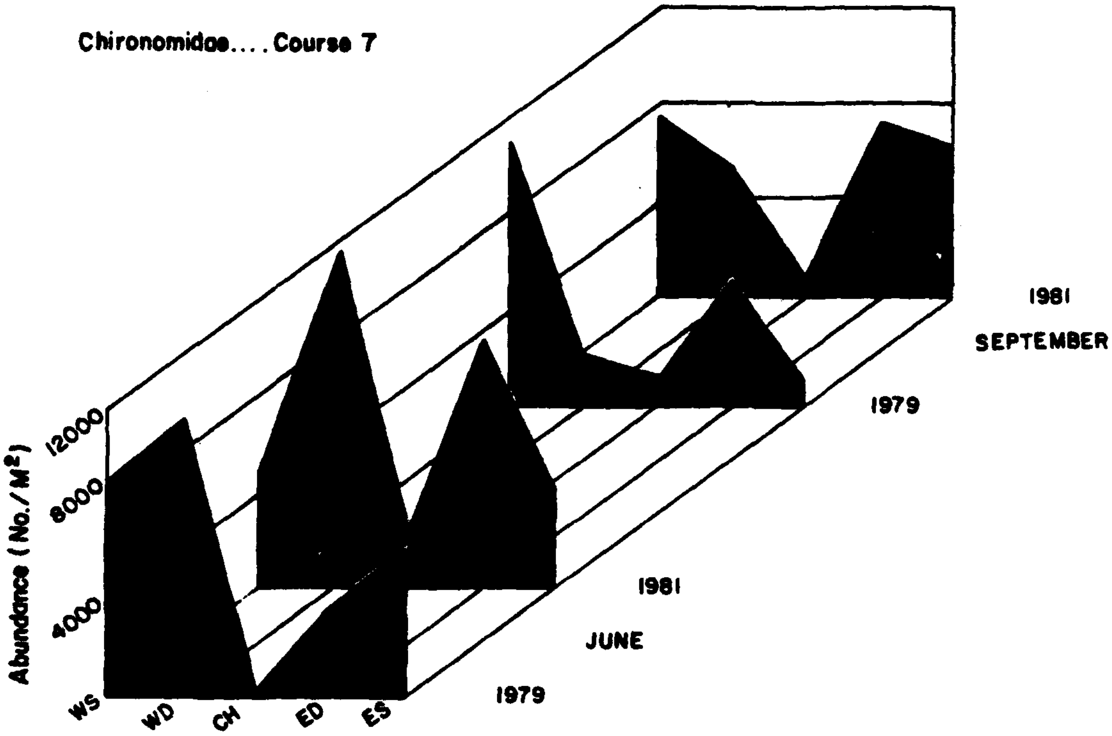


Figure 12. Comparison of 1979 and 1981 abundance of Chironomidae at Navigation Course 7 during June and September, St. Marys River. (WS = west shallow, WD = west deep, CH = channel, ED = east deep, ES = east shallow)

Chironomidae from 1979 to 1981 occurred at the east deep station during spring, the west deep station in fall and the east shallow station during fall (Figure 12).

The second most abundant taxon of benthic invertebrates at Course 7 was Oligochaeta during both years. Oligochaeta exhibited a greater proportional increase among years than most other taxa (Figure 13). Oligochaeta comprised 9.5% and 10.0% of the spring and fall, 1979, benthos but during 1981 comprised 21.0% and 16.9% of the spring and fall benthos, respectively. Greatest numbers of Oligochaeta were found at deep water stations adjacent to the navigation channel in 1981, while in 1979 greater numbers were found at shallow water stations (Figure 13).

Other common taxa which were collected in greater numbers in 1981 than 1979 included Ephemeroptera and Ceratopogonidae. Ceratopogonidae were roughly twice as common in 1981 samples as in 1979 samples. Ephemeroptera at Course 7 were comprised mostly of Hexagenia sp. Ephemeroptera were consistently collected in greater numbers on the west side of the navigation channel than the east side (Figure 14).

Common taxa which were collected in lower numbers in 1981 than in 1979 included Gastropoda, Pelecypoda, Isopoda, and Amphipoda. Gastropoda comprised 1.9 and 3.7% of the spring and fall benthos during 1979, but only 2.0 and 1.4% of the spring and fall benthos for 1981. Pelecypoda, which were present in low numbers during 1979 were uncommon at Course 7 in 1981. Isopoda comprised 8.8% of the spring, 1979, benthos but only 0.6% of the spring, 1981, benthos. Similarly, during fall isopods comprised 5.4% and 1.7% of the 1979 and 1981 benthos, respectively. Amphipoda densities were similar between years except for low numbers collected east of the navigation channel during 1981 (Figure 15).

As at Course 5 the only differences in taxonomic composition of benthos at Course 7 between years was within the Chironomidae. Predominant genera in spring 1979 included Tribelos sp., Polypedilum sp. and Procladius sp. which comprised 40.0%, 23.0% and 11.7% of the Chironomidae. In spring 1981 Tribelos sp. was absent, while Polypedilum sp., Larsia sp. and Cryptochironomus sp. comprised 37.7%, 19.8%, and 16.1% of the Chironomidae, respectively.

Navigation Course 9. Abundance of total benthic invertebrates at Course 9 during spring 1981 was 235% of that recorded in 1979 (Figure 16). During fall, however, abundances among years were almost identical when considering transect means ($9,294/m^2$ in 1979 vs. $9,032/m^2$ in 1981). Abundance of total benthos at Course 9 during spring, 1979, was significantly lower than on other sampling dates ($P < 0.10$, $X^2 = 0.10$, 3df = 6.84). As in Course 7 lowest densities of total benthos were consistently found within the navigation channel of Course 9. However, at Course 9 a greater proportion of the total benthos was collected at shallow stations when both years and seasons were considered (Figure 16).

Chironomidae were also the most abundant taxa collected from Course 9 during both years and their fluctuations are reflected in total benthos data. Spring 1981 Chironomidae densities were 243% those recorded in spring 1979 ($1,809/m^2$ in 1979 vs. $4,394/m^2$ in 1981). During fall, abundance among years was similar, but lower in 1981.

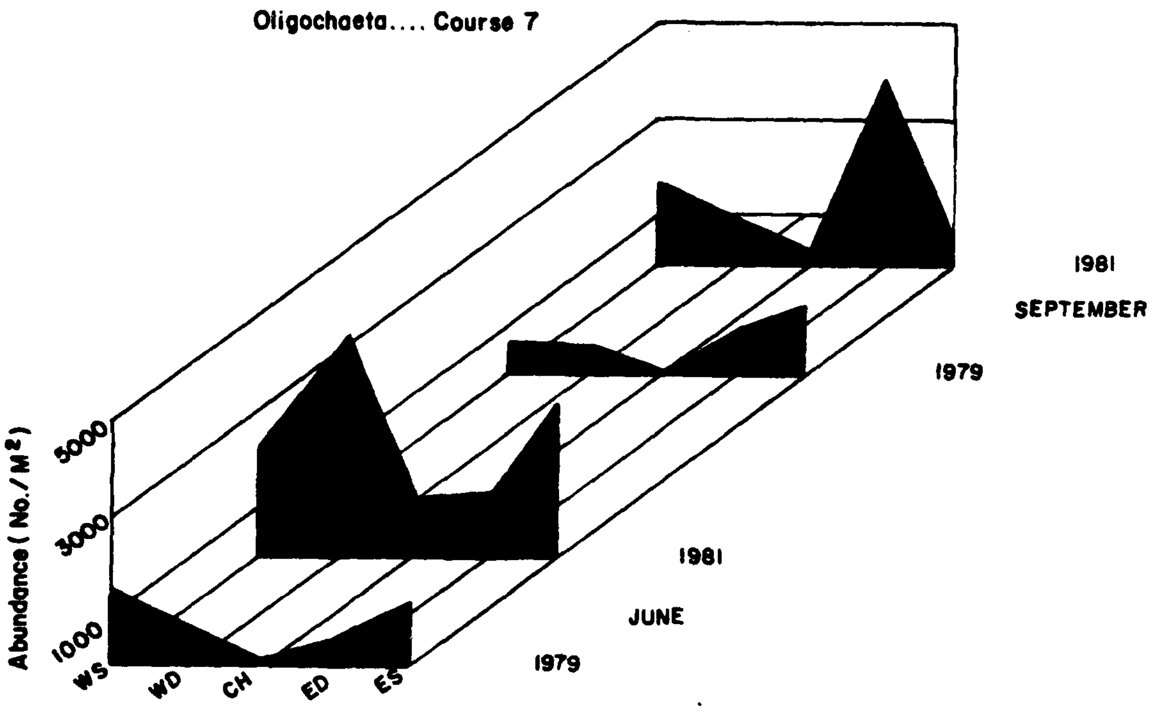


Figure 13. Comparison of 1979 and 1981 abundance of Oligochaeta at Navigation Course 7 during June and September, St. Marys River. (WS = west shallow, WD = west deep, CH = channel, ED = east deep, ES = east shallow)

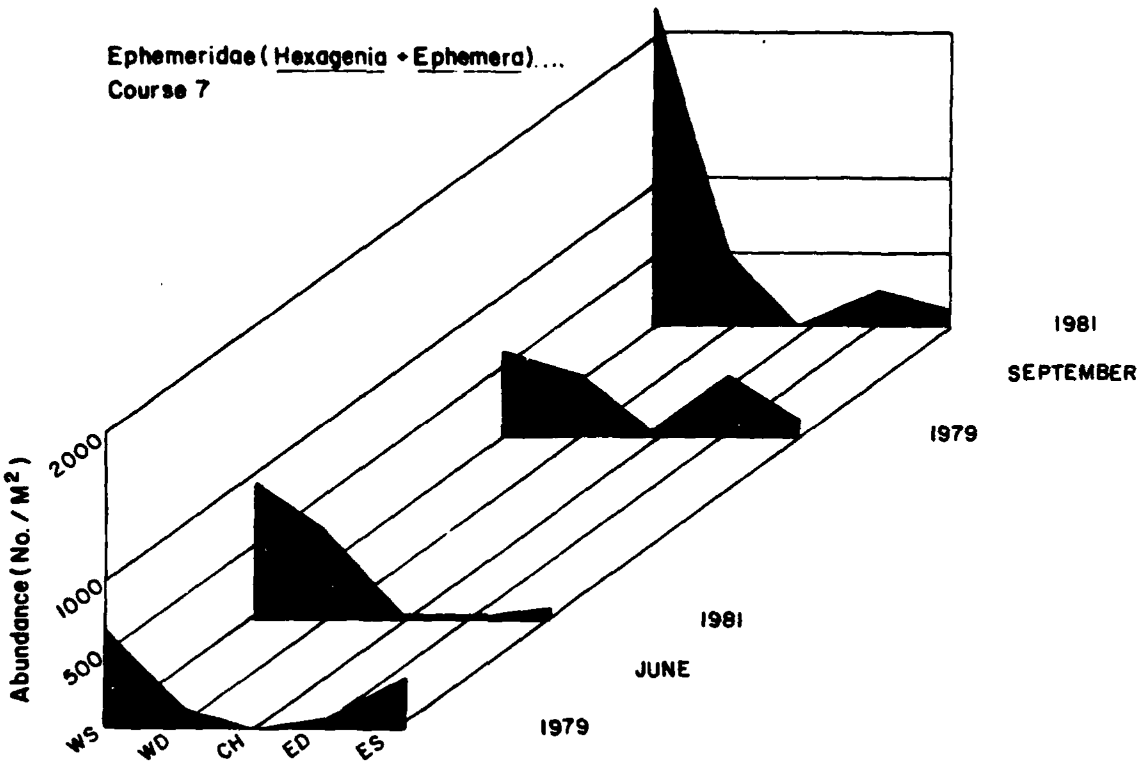


Figure 14. Comparison of 1979 and 1981 abundance of Ephemeridae at Navigation Course 7 during June and September, St. Marys River. (WS = west shallow, WD = west deep, CH = channel, ED = east deep, ES = east shallow)

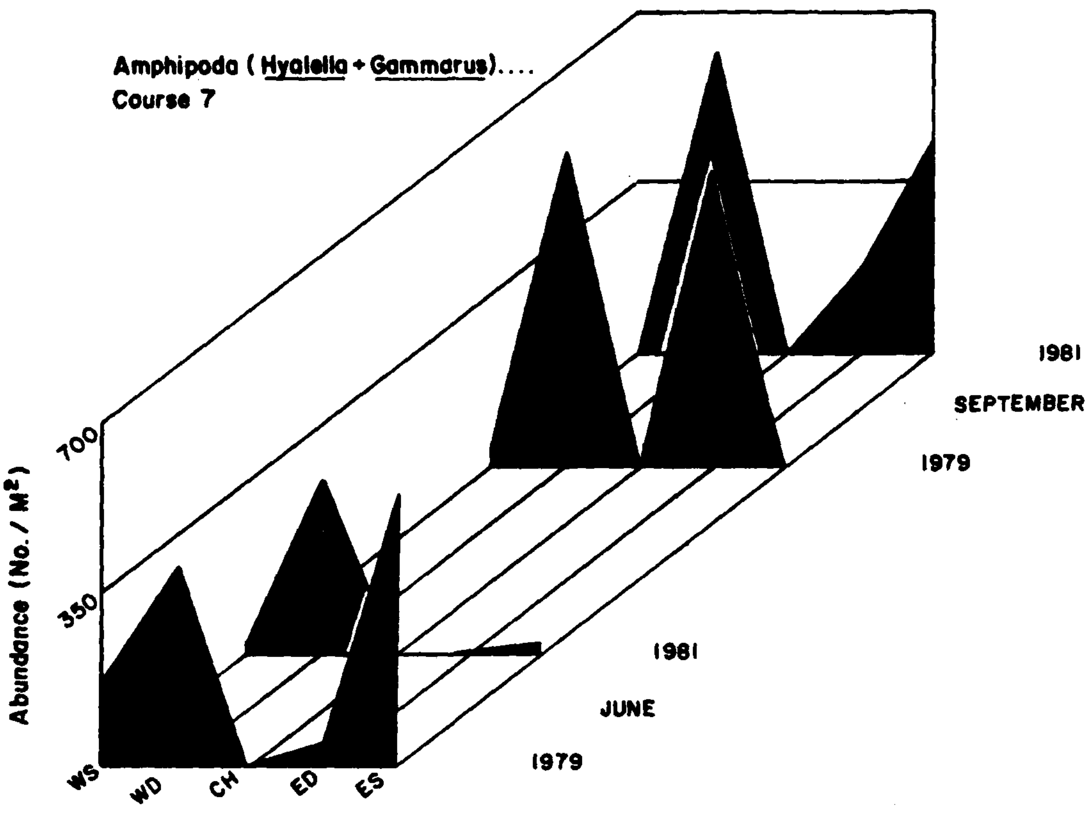


Figure 15. Comparison of 1979 and 1981 abundance of Amphipoda at Navigation Course 7 during June and September, St. Marys River. (WS = west shallow, WD = west deep, CH = channel, ED = east deep, ES = east shallow)

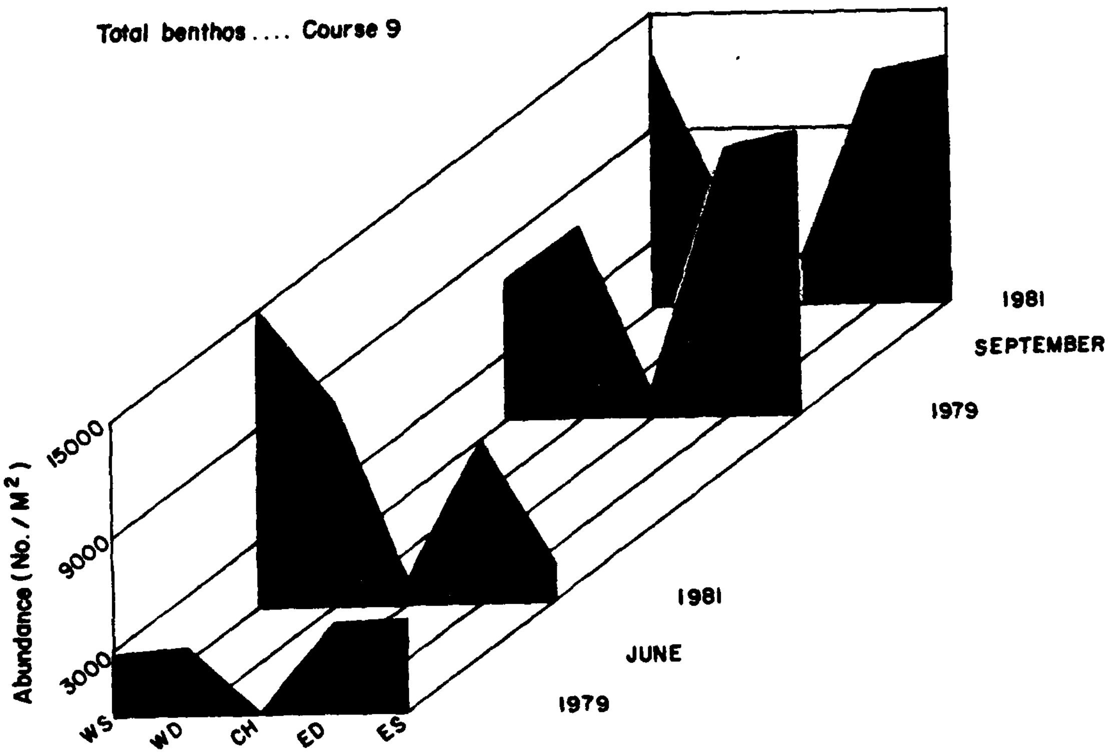


Figure 16. Comparison of 1979 and 1981 total benthos at Navigation Course 9 during June and September, St. Marys River. (WS = west shallow, WD = west deep, CH = channel, ED = east deep, ES = east shallow)

Oligochaeta were collected in greater numbers during both seasons in 1981. As at Course 7, Gastropoda were collected in greater numbers during spring 1981 than spring 1979, but this situation was reversed for fall. Pelecypoda exhibited a pattern of abundance similar to Gastropoda, except Pelecypoda numbers were less during fall 1981. Ephemeroptera was the only other common taxa which increased in abundance from 1979 to 1981. As at Course 7, Hexagenia sp. was the most common ephemeropteran at Course 9, although Caenis sp. was common at shallow stations in fall. Other common taxa either increased in abundance from 1979 to 1981 during spring, then decreased during fall or vice versa. However, abundance of these taxa were not sufficient to influence total benthic trends.

Again taxonomic differences from 1979 to 1981 were chiefly within Chironomidae. However, the ephemeropteran Caenis sp. was common at shallow stations during fall 1981, whereas only a single individual was collected in fall 1979. During spring 1979 the Chironomidae Tribelos sp. and Polypedilum sp. comprised 34% and 26% of the total Chironomidae. During spring 1981 Tribelos sp. was absent while Polypedilum sp. (14.4%), Procladius sp. (31.2%), and Larsia sp. (10.2%) were predominant genera.

Navigation Course 5 (Lake Nicolet), 1981

Eighty-three taxa of benthic invertebrates were collected from Navigation Course 5 during 1981. Many of these taxa occurred in both the vegetated littoral zone and the offshore area. Others, however, were restricted to one or the other habitat (Tables A5 through A9).

At the 3 m depth zone Chironomidae comprised 55.4% of the total benthos on a seasonal basis (28.3% - 67.3%). Polypedilum sp., Ablabesmyia sp., Procladius sp., and Larsia sp. were the most common genera comprising 33%, 22%, 10% and 9% of the Chironomidae, respectively, during all months. Polypedilum sp. and Procladius sp. were common throughout the year while Ablabesmyia sp. and Larsia sp. were most common in fall.

Oligochaeta were the second most common taxa at this station comprising 5.7% to 33.0% of the total benthos by month. Amphipoda comprised 13.2% of the benthos seasonally and 98% of these were Hyalella azteca.

Ephemeroptera at the 3 m depth included Caenis sp., Ephemera sp. and Hexagenia sp. The latter two genera each comprised 42.0% of the total Ephemeroptera of this station. Trichoptera were common, but not abundant. The most common trichopteran was Polycentropus sp. Other major taxa which were commonly collected and their predominant genera include Isopoda (Lirceus sp.), Gastropoda (Amnicola sp.) and Pelecypoda (Sphaerium sp.). Other taxa were collected in low numbers (Tables A5 through A9).

Chironomidae comprised 57.3% of the littoral zone invertebrates on a seasonal basis (range 37.5% - 72.8%). On a seasonal basis, Paratanytarsus sp. comprised 22.0% of the total Chironomidae even though it was collected only in October and December. Polypedilum sp., Larsia sp., and Procladius sp. were also common in the littoral zone comprising 21.5%, 16.5% and 11.4% of the Chironomidae, respectively. The other common offshore genera, Ablabesmyia sp., was uncommon in the littoral zone.

Seven genera of Ephemeroptera were collected from the littoral zone compared to 5 offshore, Callibaetis sp. and Ameletus sp. were taken in the littoral zone, but not offshore. The predominant ephemeropteran in this area was Caenis sp. comprising 93% of the seasonal Ephemeroptera.

Ten genera of Trichoptera were collected in the littoral zone. Six of these genera were not collected offshore. The predominant trichopteran, however, was Polycentropus sp. which is also common at the 3 m depth.

Amphipoda comprised 5.6% of the total benthos of the littoral zone seasonally. The predominant amphipod was Hyalella azteca, but Gammarus sp. was also common in the littoral zone. Isopoda were much more common in littoral samples than offshore samples comprising 6.8% of the total benthos of the littoral zone seasonally. Whereas Lirceus sp. was predominant offshore, Asellus sp. comprised more than 80% of the littoral isopods.

Oligochaeta were common in the littoral zone also comprising 14.9% of the total benthos seasonally. Although not routinely identified littoral oligochaetes were mostly Naididae.

Other taxa which characterized the littoral zone included Sigara sp. (Corixidae), Enallagma sp. (Zygoptera), Ferrissia sp. (Gastropoda), and Paraponyx sp. (Lepidoptera). In addition Ostracoda were common in August through December samples.

Abundance of total benthic invertebrates was greater in the littoral zone of Navigation Course 5 than at the 3 m depth (Figure 17). Seasonal means were $18,506/m^2$ in the littoral zone and $13,771/m^2$ at the 3 m depth. Greatest abundance occurred during October in both areas. Seasonal maxima in the littoral zone was $32,853/m^2$ while seasonal maxima offshore was $24,280/m^2$. From April through August, total invertebrate abundance at the two sites appeared out of phase (Figure 17). During April and August densities in the littoral zone were greater than offshore, while in June the opposite was true.

Total benthic invertebrate abundance under ice during March was very low. Mean abundance from 6 PONAR grab samples was $385/m^2$ (Table A10). The only taxa occurring in more than one sample included Empididae, Cricotopus sp., Orthocladius sp. (Chironomidae), and Oligochaeta.

Lake George

As in other areas of the St. Marys River, Chironomidae were the most common taxa recorded at the 3 m depth station of Lake George comprising 46.1% of the benthos seasonally. Predominant genera on a seasonal basis included Polypedilum sp., Ablabesmyia sp., Larsia sp., and Procladius sp. comprising 34.9%, 23.4%, 12.3% and 10.8% of the total Chironomidae, respectively (Tables A11 through A15). Cryptochironomus sp. and Dicrotendipes sp. were common on certain sampling dates.

Unlike other areas of the river sampled, Ephemeroptera were the second most abundant taxa at the 3 m depth comprising 12.5% of the total benthos

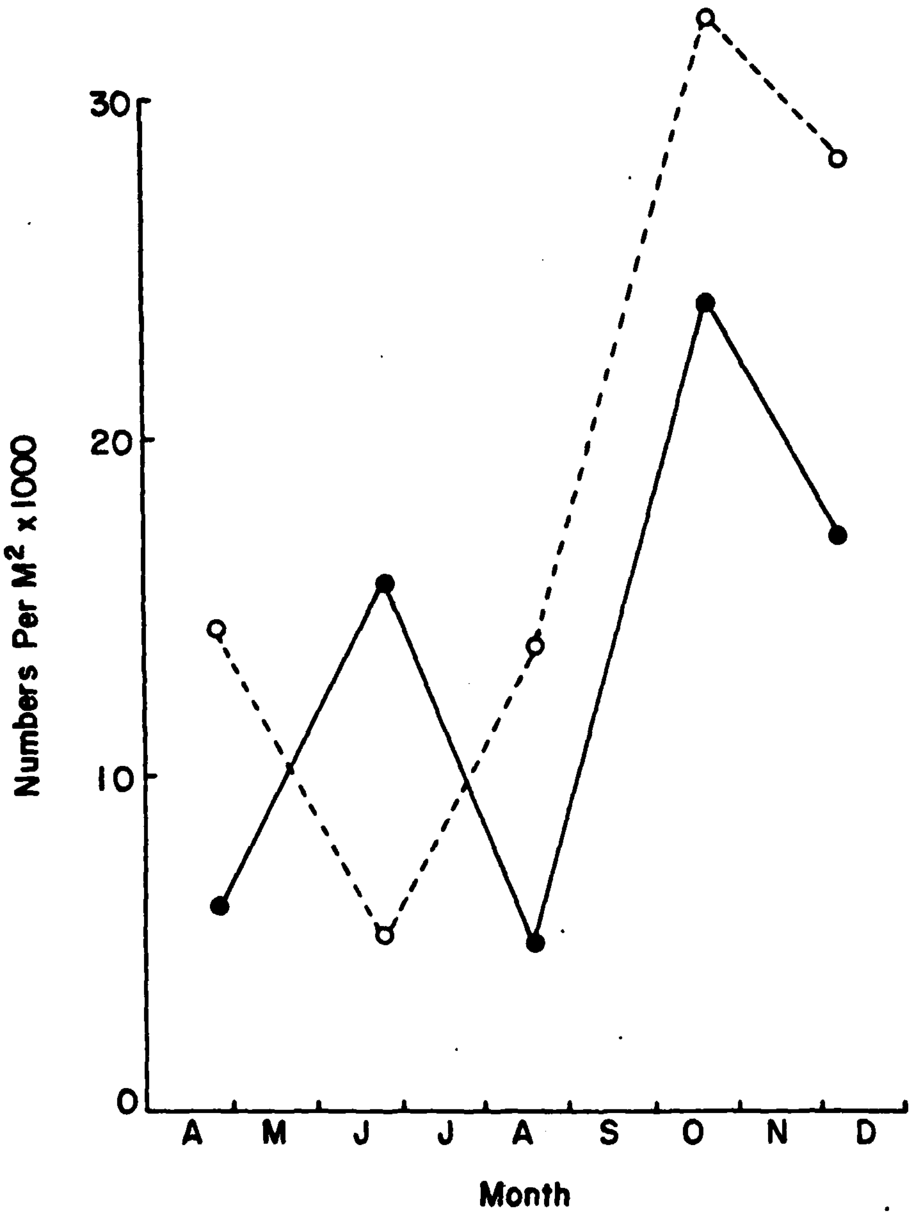


Figure 17. Seasonal abundance of total benthic invertebrates at the 3 meter depth zone (solid circles) and in the vegetated littoral zone (open circles) of Navigation Course 5 during 1981.

seasonally. Hexagenia sp. was the most common genera comprising 73.8% of the Ephemeroptera and 1.7% to 19.0% of the total benthos. Ephemera sp., Caenis sp., and Leptophlebia sp. were also collected at this station.

Trichoptera comprised 2.3% of the benthos seasonally at this station. Polycentropus sp. comprised 33.8% of the Trichoptera, however, Phylocentropus sp. occurred more regularly. The only other insects collected from the 3 m depth were an individual Nymphula sp. (Lepidoptera) and Ceratopogonidae (Tables A11 through A15). Ceratopogonidae were common at this station and made up 3.8% of the benthos seasonally.

Mollusks were sometimes abundant in Lake George. Seasonally Pelecypoda comprised 8.4% (0.2 - 19.1%) and Gastropoda 4.7% (0.6 - 16.6%). Common genera included Pisidium sp., and Sphaerium sp. which comprised 54.2% and 45.6% of the Pelecypoda. Amnicola sp. comprised 90.3% of Gastropoda collected.

Amphipoda were also common offshore in Lake George and comprised 8.2% of the benthos seasonally. Most of the Amphipoda were Hyalella azteca. Isopoda were less common (2.7% of the benthos seasonally) and Lirceus sp. outnumbered Asellus sp. roughly 10:1 at this station. The other common component of the benthos at this station were Oligochaeta which comprised 12.3% of the benthos seasonally.

Chironomidae were also the predominant organism in samples from the Lake George littoral zone. Forty-four percent of the benthos collected were Chironomidae on a seasonal basis (Tables A11 through A15). Larsia sp. comprised 19.9% of the Chironomidae seasonally even though it was collected only in June and October. In October Larsia sp. made almost one half of the Chironomidae. Other common genera included Polypedilum sp. and Ablabesmyia sp. comprising 12.8% and 11.1% of the Chironomidae seasonally. Dicrotendipes sp. was also common in the Lake George littoral zone.

Oligochaeta were more common in the Lake George littoral samples than elsewhere and comprised 27.7% of the benthos from this site seasonally. During June and August Oligochaeta comprised 40.0% and 59.6% of the total benthos, while in April they comprised 12.4% of the total.

Ephemeroptera comprised 6.1% of the benthos seasonally. The predominant genera (82.6% of the Ephemeroptera) was Caenis sp. The only other taxon comprising more than 5% of the benthos seasonally was Ostracoda (6.8%). However, this was due to large numbers collected in October as Ostracoda were taken only in August and October.

Other major taxa accounted for relatively low percentages of the total benthos, because of the high densities of other organisms. These major taxa and their predominant genera included Trichoptera (Polycentropus sp.), Lepidoptera (Nymphula sp.), Amphipoda (Hyalella azteca), Isopoda (Asellus sp.), and Gastropoda (Ferrissia sp.).

Benthic invertebrates were more abundant in the littoral zone of Lake George than the 3 m depth on all dates except April (Figure 18). Seasonal mean

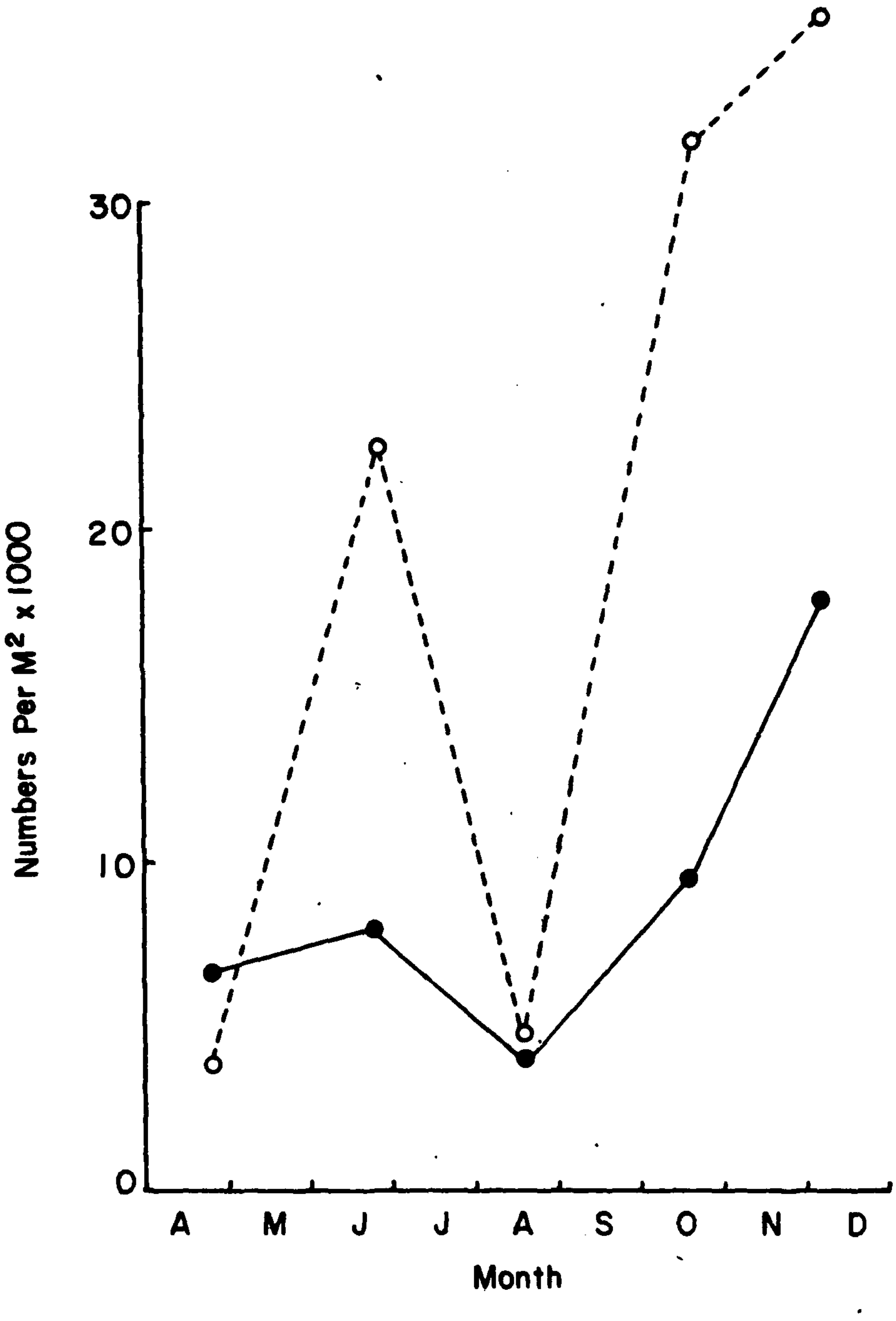


Figure 18. Seasonal abundance of total benthic invertebrates at the 3 meter depth (solid circles) and in the vegetated littoral zone (open circles) of Lake George during 1981.

abundance in the littoral zone was 17,915.2/m^2 while at the 3 m depth it was 9,084.4/m^2. Lowest densities were recorded in April and August, although a June peak in abundance was found between these dates. Greatest densities were recorded in fall, and seasonal maxima of 36,476/m^2 occurred in December.

Densities in April and June at the 3 m depth station were comparable. The seasonal minima (3,619/m^2) was recorded in August. Autumn densities were greater than spring or summer. The seasonal maxima (18,011/m^2) at this site also occurred in December.

Secondary Productivity, Navigation Course 5 and Lake George

Benthic standing crop was greater in the littoral zone of Navigation Course 5 than at the 3 m depth. Seasonal mean standing crop within the littoral zone was 6,386.7 mg/m^2 while at the 3 m depth it was 4,550.0 mg/m^2 dry weight. The seasonal minimum standing crop in the littoral zone occurred in June (1,097.0 mg/m^2) whereas the seasonal minimum at 3 meters occurred in August (2,917.7 mg/m^2, Figure 19). Seasonal maximum standing crop within the littoral zone occurred in December (10,449.4 mg/m^2) and in October at the 3 m depth (5,634.5 mg/m^2).

Total annual production was calculated for 15 common invertebrates. In Course 5, the sum of these production estimates was similar at the 3 m depth (10,704.2 mg/m^2/yr) and in the littoral zone (11,318.9 mg/m^2/yr). Greatest production at the 3 m depth was achieved by the amphipod *Hyalella azteca* and the chironomid *Polypedilum* sp. with each exceeding 2,200 mg/m^2/yr (Table 3). Other common genera contributing substantial production included *Ablabesmyia* sp., *Procladius* sp., *Lirceus* sp., *Ephemera* sp. and *Hexagenia* sp. in decreasing order (Table 3).

Greatest production within the littoral zone was achieved by *Asellus* sp., an isopod (2,776.7 mg/m^2/yr). Production of *Polypedilum* sp. in the littoral zone exceeded 1,500 mg/m^2/yr while four other genera were found to have production exceeding 1,000 mg/m^2/yr including *Procladius* sp., *Caenis* sp., *Hyalella azteca*, and *Lirceus* sp.

Annual production to seasonal mean biomass ratios (P/B ratio) generally were in the range of 2 - 6 at both sites (Table 4). However, *Hexagenia* sp. and *Asellus* sp. had P/B ratios slightly less than 2 at the 3 m depth and *Polypedilum* sp. also had a lower P/B ratio in the littoral zone. *Sphaerium* sp. had very low P/B ratios at both sites (Table 4). High P/B ratios were exhibited by *Polycentropus* sp. at both sites and by *Ephemera* sp. in the littoral zone.

The benthic standing crop in Lake George was greater offshore than in the littoral zone. Seasonal mean standing crop at 3 meters was 17,183.4 mg/m^2 compared to 6,688.3 mg/m^2 in the littoral zone. Seasonal minimum standing crop (6,906.4 mg/m^2) occurred in August at the 3 m depth and in April (693.9 mg/m^2) in the littoral zone (Figure 20). Seasonal maximum standing crops were found in June at the 3 m depth (32,076.4 mg/m^2) and in October in the littoral zone (16,152.3 mg/m^2).

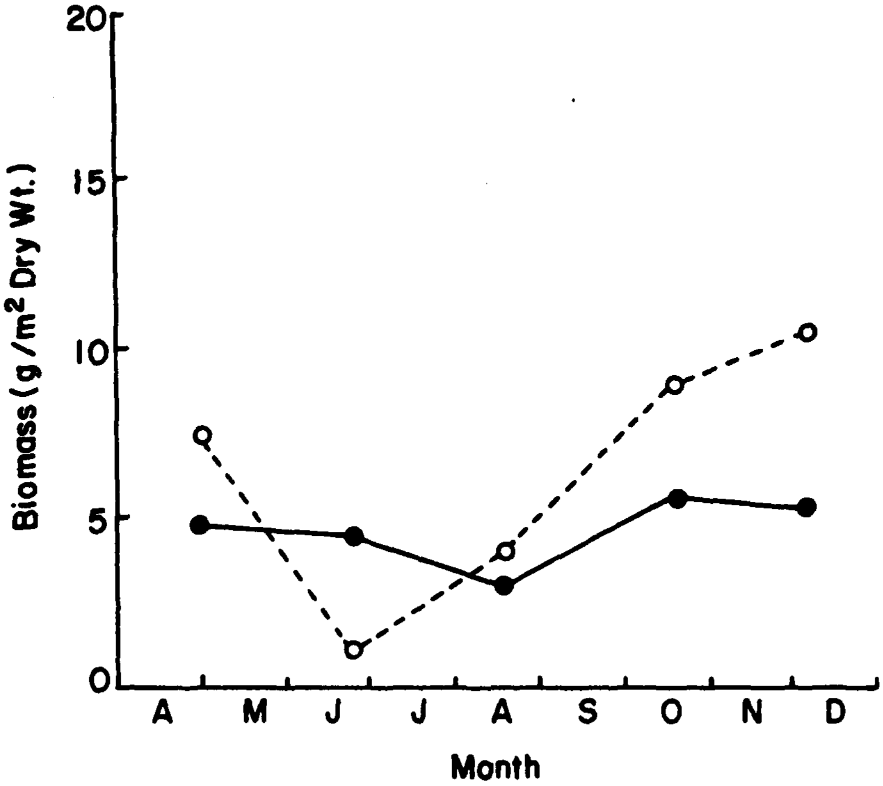


Figure 19. Seasonal standing crop as biomass in g/m^2 dry weight in Navigation Course 5 at the 3 meter depth (solid circles) and in the vegetated littoral zone (open circles) during 1981.

Table 3. Production estimates for common invertebrate taxa occurring in the vegetated littoral and 3 meter depth areas of Navigation Course 5 and Lake George, St. Marys River, 1981. Units are mg · m2 · yr dry weight.

Taxa	Navigation Course 5		Lake George	
	3 Meter	Littoral	3 Meter	Littoral
Ephemeroptera				
Caenis sp.	80.3	1,155.1	131.7	1,284.1
Ephemera sp.	774.1	19.9	199.0	10.7
Hexagenia sp.	762.0	46.9	6,206.4	94.5
Trichoptera				
Polycentropus sp.	228.9	279.7	185.6	96.9
Chironomidae				
Ablabesmyia sp.	1,069.0	90.4	453.1	411.6
Cryptochironomus sp.	466.3	536.7	551.6	330.6
Larsia sp.	299.0	596.3	156.3	487.7
Polypedilum sp.	2,205.0	1,519.7	1,196.7	838.5
Procladius sp.	1,044.8	1,192.4	658.9	593.8
Stictochironomus sp.	55.3	452.0	9.7	95.4
Amphipoda				
Hyalella azteca	2,227.7	1,147.6	911.6	811.7
Gammarus sp.	85.8	354.4	129.3	111.1
Isopoda				
Asellus sp.	25.2	2,776.7	116.5	645.0
Lirceus sp.	983.8	1,007.7	791.6	306.3
Pelecypoda				
Sphaerium sp.	397.0	143.5	4,346.7	53.4
TOTAL	10,704.2	11,318.9	16,046.5	6,171.2

Table 4. Annual P/B ratios (production/biomass) for common invertebrate taxa occurring in the vegetated littoral and 3 meter depth areas of Navigation Course 5 and Lake George, St. Marys River, 1981.

Taxa	Navigation Course 5		Lake George	
	3 Meter	Littoral	3 Meter	Littoral
Ephemeroptera				
Caenis sp.	3.816	6.745	3.535	3.990
Ephemera sp.	2.252	18.308	2.370	5.760
Hexagenia sp.	1.885	2.135	1.786	7.291
Trichoptera				
Polycentropus sp.	8.245	6.806	7.173	7.517
Chironomidae				
Ablabesmyia sp.	3.669	4.516	2.174	3.930
Cryptochironomus sp.	5.901	7.697	5.090	6.182
Larsia sp.	3.720	5.405	2.242	3.539
Polypedilum sp.	2.475	1.656	1.815	1.601
Procladius sp.	3.039	2.891	3.059	2.859
Stictochironomus sp.	7.416	2.348	6.922	1.831
Amphipoda				
Hyalella azteca	4.145	4.061	3.962	4.208
Gammarus sp.	2.866	3.138	5.057	3.481
Isopoda				
Asellus sp.	1.742	3.642	4.895	3.236
Lirceus sp.	4.238	2.241	3.952	2.105
Pelecypoda				
Sphaerium sp.	0.128	0.157	0.119	0.120

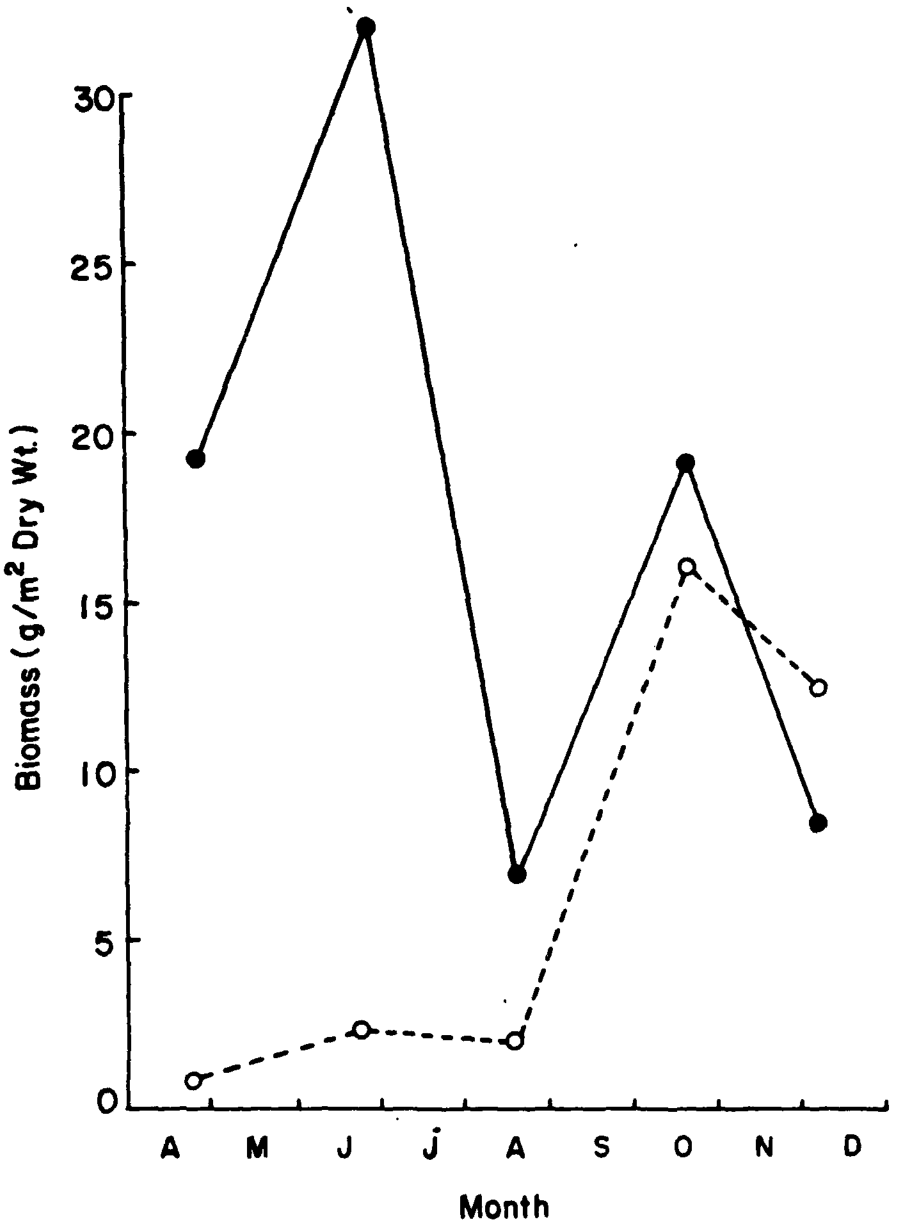


Figure 20. Seasonal standing crop as biomass in g/m^2 dry weight in Lake George at the 3 meter depth (solid circles) and in the vegetated littoral zone (open circles) during 1981.

The sum of production estimates from the 3 m depth in Lake George (16,046.5 $mg/m^2/yr$) was greater than that (6,171.2 $mg/m^2/yr$) found in the littoral zone (Table 3). Production estimates for Hexagenia sp. (6,206.4 $mg/m^2/yr$) and Sphaerium sp. (4,346.7 $mg/m^2/yr$) at the 3 m depth of Lake George were the greatest for any taxa at all sites examined. Polypedilum sp., Hyalella azteca, and Lirceus sp. also together contributed 18.1% of the calculated production offshore at Lake George (Table 3).

Greatest production in the littoral zone of Lake George was achieved by Caenis sp. (1,284.1 $mg/m^2/yr$). Polypedilum sp., Hyalella azteca, Asellus sp. and Procladius sp. also contributed a substantial portion of the production in the littoral zone.

Annual production to mean seasonal biomass ratios from Lake George were also generally in the 2 - 6 range. As at Navigation Course 5, Sphaerium sp. P/B ratios were much less than one at both sites in Lake George (Table 4). Polypedilum sp. had P/B ratios slightly less than 2 at both sites, while Polycentropus sp. exhibited ratios greater than 7.

AQUATIC MACROPHYTES

Emergent and Submersed Plants in Navigation Courses 5 and 7, and in Lake George

General qualitative observations regarding aquatic vegetation of the St. Marys River came out of studies made in the Neebish Island region during 1979 and 1980. Macrophytes appeared to be dominated by relatively few species. These occupied very large tracts (km^2), either as emergent shoreline stands or low-growing submersed plant cover. Scirpus acutus (hard-stem bulrush) tended to dominate the vegetation in outer portions of emergent stands. Scirpus americanus (3-square bulrush) and Eleocharis smallii (spike rush) were locally abundant, but confined to shallower water than S. acutus. The last species tended to be common in shoreward portions of emergent stands as well as at the outer fringe of vegetation. Sparganium eurycarpum (bur reed) and Equisetum fluviatile (horsetail) were locally abundant with S. acutus in shoreward portions of emergents stands. A tight, low-growing (2 - 3 cm) carpet of submersed plants dominated by Ranunculus reptans and Juncus pelocarpus forma submersus was intermingled with emergent plants where sandy sediments occurred.

The most conspicuous submersed plant in the Neebish Island region was Potamogeton richardsonii. The plant occurred in clusters of leafy stems that grew upward from groups of rhizomes to within decimeters of the water's surface. However, clumps of these plants occupied relatively small areas (100 m^2). Much less conspicuous, but of far greater importance in terms of area occupied and density, were Isoetes riparia (quillwort) and the charophytes, Nitella flexilis and Chara globularis. They grew low to the bottom (3 - 25 cm) in depths greater than 2 m, and were not easily seen from the surface.

Studies in 1981 were designed to begin to quantify aspects of aquatic vegetation in the River, and to test the validity of earlier qualitative observations. Baseline data were gathered at locations that could be sampled

with the same techniques in future years to substantiate stability or change in the system.

Figure 21 presents patterns of horizontal distribution of high biomass stands of aquatic plants along transects in Lake George, Lake Nicolet, and Course 7 of the Upbound Neebish Channel. It also shows ranges of depth occupied by the important types of vegetation. Scirpus acutus dominated shallow water at the shore of the study site on Lake George. It grew to a depth of ca. 1.5 m. Scirpus americanus occupied a similar position on the transect in Lake Nicolet; it occurred to water depth 0.6 m. Emergent vegetation was absent at Course 7. The most obvious environmental difference between the two emergent-occupied sites and the shallows of Course 7 was sediment type. A mixture of clay and sand with organic detritus was found in bulrush beds at Lake George and Lake Nicolet. Rock with small patches of sand covered the bottom of the inshore portion of the transect at Course 7. The relationship between particle size in sediments and mean current velocity over sediments is well known from the literature. The observed difference in sediment types implies a difference in exposure of sediments at these sites to movements of water over them. Small particles have not accumulated inshore at Course 7 because of relatively high velocity of movements of water in that area. Existing sediments also were not suitable for emergent plant habitation.

A broad sand bench occurred offshore of the emergent plant bed on the transect in Lake Nicolet. This bench, devoid of vegetation as shown in Figure 21, extended for approximately 3800 m along the east shore of Lake Nicolet, from below Nine Mile Point to above Shingle Point. The occurrence of a similar large bench in Lake Nicolet off the northwest shore of Neebish Island was documented in aquatic vegetation studies presented by Liston et al. (1980). Since vegetation was found elsewhere in the River system at depths of these benches (e.g. Scirpus acutus in Lake George and Isoetes riparia along Course 7 as shown in Figure 21), its absence in Lake Nicolet was taken as evidence that the environment of the benches was hostile for plant colonization. Shifting of sand on the benches, caused by exposure to down-slope River currents or waves, is a logical explanation for this.

Isoetes riparia was the dominant inshore submersed plant on transects in Lake George and along Navigation Course 7 (Figure 21). Beds of this plant occupied sandy-clay sediments in the depth range of 1 - 3.5 m. Large beds of this plant (e.g. 1 km uninterrupted on transect) were found within this depth range in Lake Nicolet north of Neebish Island during 1979 (Liston et al. 1980). While the plant has been found growing to depth 5 m, the depth limit for development of beds in the Neebish Island region was confirmed in 1980 at 3.5 m (Liston et al. 1981). The condition of I. riparia on transects in Lake George and Course 7 was typical of beds of this dominant plant at other locations in the River.

The deepest growing plants on transects in Lake Nicolet and along Upbound Course 7 were charophytes (Figure 21). Nitella flexilis occurred monotypically in charophyte beds at depths greater than 5 m at both sites. Species of Chara, particularly Chara globularis, grew mixed with N. flexilis in more shallow portions of charophyte beds. Charophyte beds were absent on the transect in Lake George. However, the plant was present in Lake George; occasional shoots

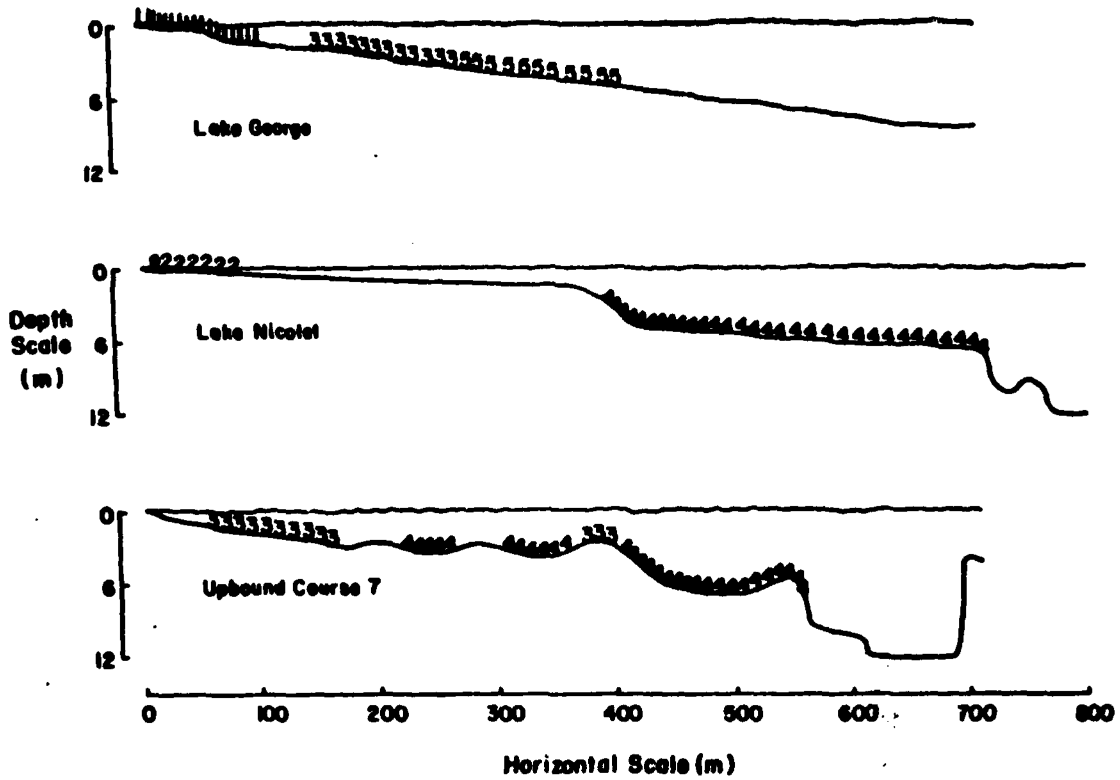


Figure 21. Distribution of dominant vegetation along depth profiles of transects used for aquatic plant studies on the St. Mary's River in 1981. *Scripus acutus* (1), *Scirpus americanus* (2), *Isoetes riparia* (3), charophytes dominated by *Nitella flexilis* (4), and *Potamogeton robbinsii* (5).

were taken in biomass samples collected on the transect there. As shown in Figure 21, a bed of Potamogeton robbinsii grew in deep water on the Lake George transect. The plant has been collected previously from waters of the Neebish Island region (Liston et al. 1980), but well developed beds like those of Lake George have not been observed on the main-stem of the River during 1979 - 1981. There is no basis from these studies by which to judge the environmental significance, if any, of the absence of well developed charophyte beds on the Lake George transect, or the presence of a mature stand of P. robbinsii there and the absence of such in waters of the Neebish Island region.

Biomass was determined during 1981 in the beds of vegetation shown in Figure 21. Samples were taken on four occasions during the ice-free season. Results of this work are given in Appendix Tables B1 through B9. Data are provided there on secondary as well as dominant species. The discussion below is directed toward dominant plants.

Figure 22 shows curves for the accumulation of biomass in live above-soil shoots of Scirpus acutus in inshore and offshore portions of its bed on the transect in Lake George. Germination of shoots from rootstocks began earlier inshore than offshore. Maximum biomass was reached in the inshore portion of the stand in late July. It persisted in the range of 530 - 540 g AFDW m^{-2} from then through the last measurement in early September. During the period of maximum biomass, shoots were 1.7 - 1.8 m high (above the hydrosoil), and had a density of 155 - 160 shoots m^{-2}. Maximum seasonal biomass was present in the offshore portion of the bed in late July. Plants offshore attained the same mature height as inshore plants. However, offshore density at maximum biomass was one-half of that measured inshore: 75 - 80 shoots m^{-2}. Maximum offshore biomass was similarly low: 240 - 260 g AFDW m^{-2} occurred in the late July to September interval.

The emergent plant bed on the transect in Lake Nicolet was dominated by the bulrush, Scirpus americanus. In 1981, shoots of this plant germinated from rootstocks during the last part of May. Figure 23 shows seasonal biomass for shoots in the Lake Nicolet bed of this species. It did not reach its maximum seasonal biomass on this site until September. Biomass of S. americanus in the inshore portion of the stand in early September was 152 g AFDW m^{-2}. Density at that time was 214 shoots m^{-2}; mean height above the hydrosoil was 0.8 m. It should be noted that the diversity of vegetation in the shallow, inshore portion of this stand was high, and biomass measured in early September for secondary species taken together was higher (185 g AFDW m^{-2}) than for S. americanus (Table B5). The offshore portion of the emergent stand on the Lake Nicolet transect was nearly monotypic S. americanus (Table B6). Maximum seasonal biomass of shoots observed there was 272 g AFDW m^{-2}. Plants had a mean height of 1.0 m, and a density of 305 shoots m^{-2} at the time of maximum biomass.

A comparison of data from emergent bulrush beds on Lake George and Lake Nicolet showed differences attributable to growth habits of the two dominant species. In the most well developed portions of their beds, S. acutus was 1.5 times taller than S. americanus at maturity (1.5 vs. 1.0 m), grew one-half as dense (160 vs. 305 shoots m^{-2}), and had twice the biomass (540 vs. 272 g AFDW m^{-2}). In relative terms, individuals of S. acutus were large and widely spaced, while individuals of S. americanus were small and densely packed.

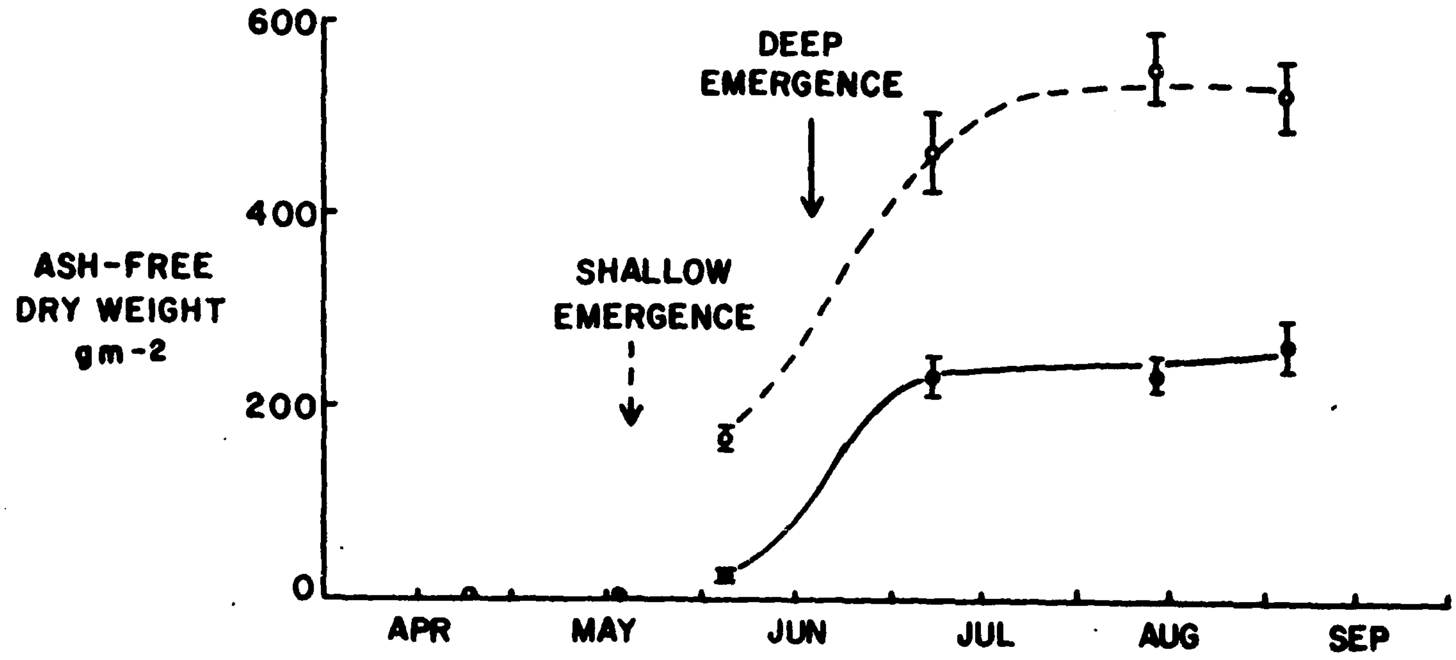


Figure 22. Biomass of live shoots of the bulrush, *Scirpus acutus*, on the Lake George transect in 1981. Curves are shown for shallow growing plants (0.3-0.7 m -----) and deep growing plants (0.7-1.5 m ———); one standard error of means is shown. Estimated germination dates are given on the horizontal axis; average time of emergence through the water's surface is given.

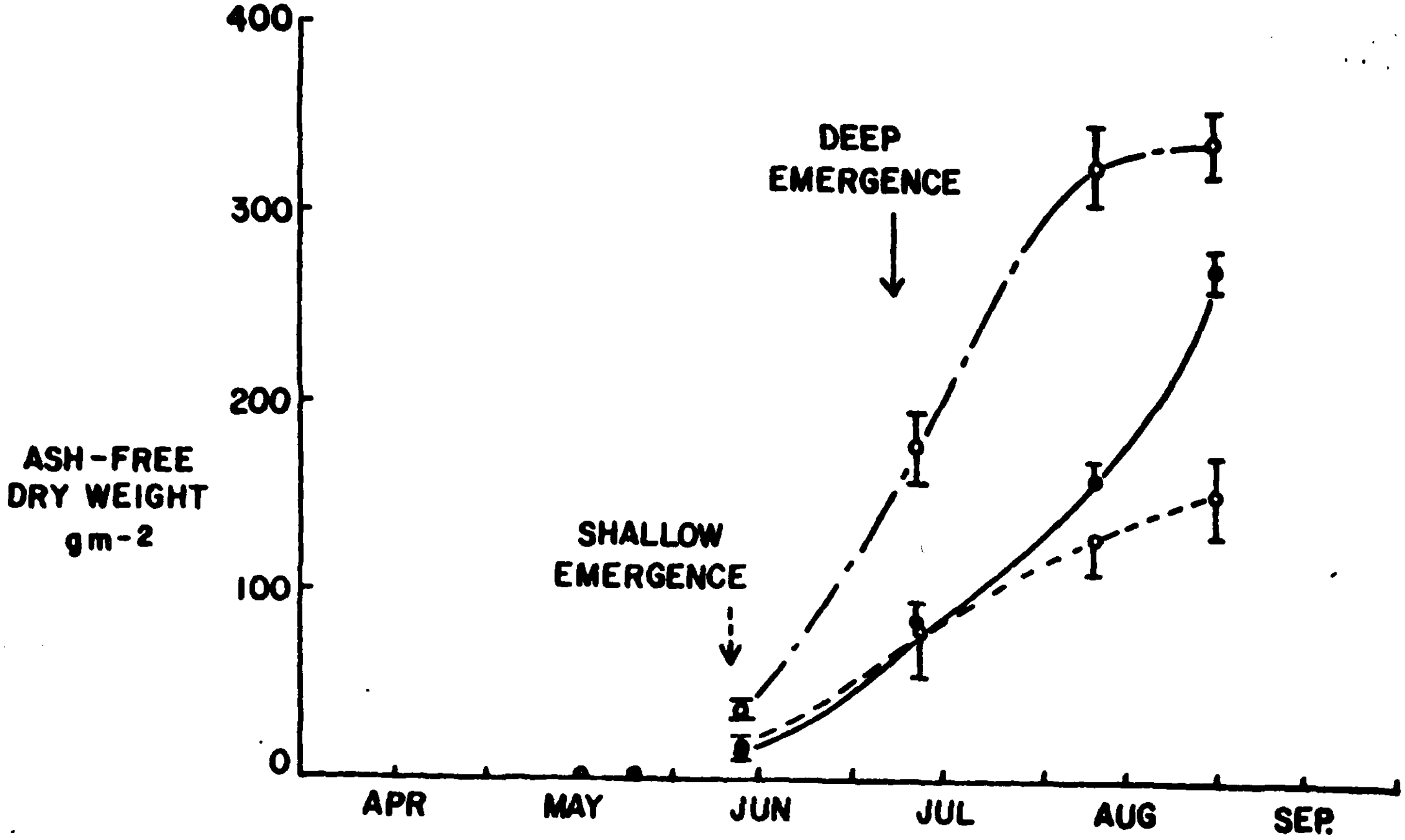


Figure 23. Biomass of emergent plants on the Lake Nicolet transect in 1981. Curves are shown for total biomass in the shallow portion of the emergent stand (0.2-0.3 m —— - ——), *Scirpus americanus* in the shallow portion of the stand (0.2-0.3 m -----), and *Scirpus americanus* in the deep portion of the stand (0.4-0.6 m ———); one standard error of means is shown. Estimated germination dates are given on the horizontal axis; average time of emergence of *S. americanus* through the water's surface is shown.

The larger species (S. acutus) grew to a greater depth along transects: 1.5 m as compared to the 0.6 m depth reached by S. americanus (Figure 21).

Amounts of biomass in submersed plant beds on the transects are shown in Figures 24 and 25. Data are given in these Figures for Isoetes riparia and charophytes; additional measurements made in beds of these plants are found in Appendix Tables B3, B7, B8, and B9. Biomass in the bed of Potamogeton robbinsii at Lake George (Figure 21) was low (less than 18 g AFDW m^{-2}) throughout the season (Table B4). Its pattern of seasonal change in biomass was similar to that for I. riparia and charophytes. Items in the discussion of these high biomass submersed plants given below are applicable to P. robbinsii as well.

Temperature and light, important regulators of plant growth, characteristically increase together in the spring in the temperate zone. In response to this, impressive increases in biomass of photosynthetic tissue, like those shown for species of Scirpus in Figures 21 and 22, commonly occur. This is true for submersed plants, as well as for emergent and terrestrial species. However, the increase in biomass is most obvious in those plants that abscise photosynthetic tissue in the fall; those with the deciduous habit.

As shown in Figures 24 and 25, impressive growing season increases in submersed plant biomass did not occur in dominant species at study sites in the St. Marys system, except for charophytes on the Lake Nicolet transect. Biomass in other submersed beds tended to remain constant over the period of sampling.

Field observations suggest to us that the tendency toward nearly constant growing season biomass occurred in beds of plants where dead or dying tissue of the previous growing season was sluffed at a rate approximately equal to the rate of replacement of biomass by new growth. We postulate that submersed vegetation produced in a growing season remains in beds beneath the ice of the St. Marys River through the winter. The photosynthetic thalli of charophytes and leaves of Isoetes riparia die back slowly and degenerate poorly at low water temperatures in winter. The amount of moribund tissue retained in a bed over-winter is determined by the degree of exposure of the bed to water currents; currents with adequate energy remove dead vegetation from beds prior to the next growing season (e.g. charophyte bed on Lake Nicolet transect). Because of water temperatures too low for germination of new shoots, biomass in the river in the spring is dominated by degenerating tissue of the previous year. In beds protected from currents, that moribund tissue is sluffed during the growing season as new biomass accumulates.

Water over submersed plant beds in the river warmed slowly in the spring of 1981. It reached 5°C by dates in May shown in Figures 24 and 25. It warmed with occasional sporadic episodes, to an annual maximum by the latter part of August. The character of plant tissues in biomass collections changed for both charophytes and I. riparia in this interval. Charophytes in June were brownish-green, slimy to the touch, and tended to have loosely associated (non-attached) macroscopic filamentous algae intermingled in the beds. In August and September, charophytes were bright green, firm and crisp to the touch, and without associated macroscopic algae. We propose that the

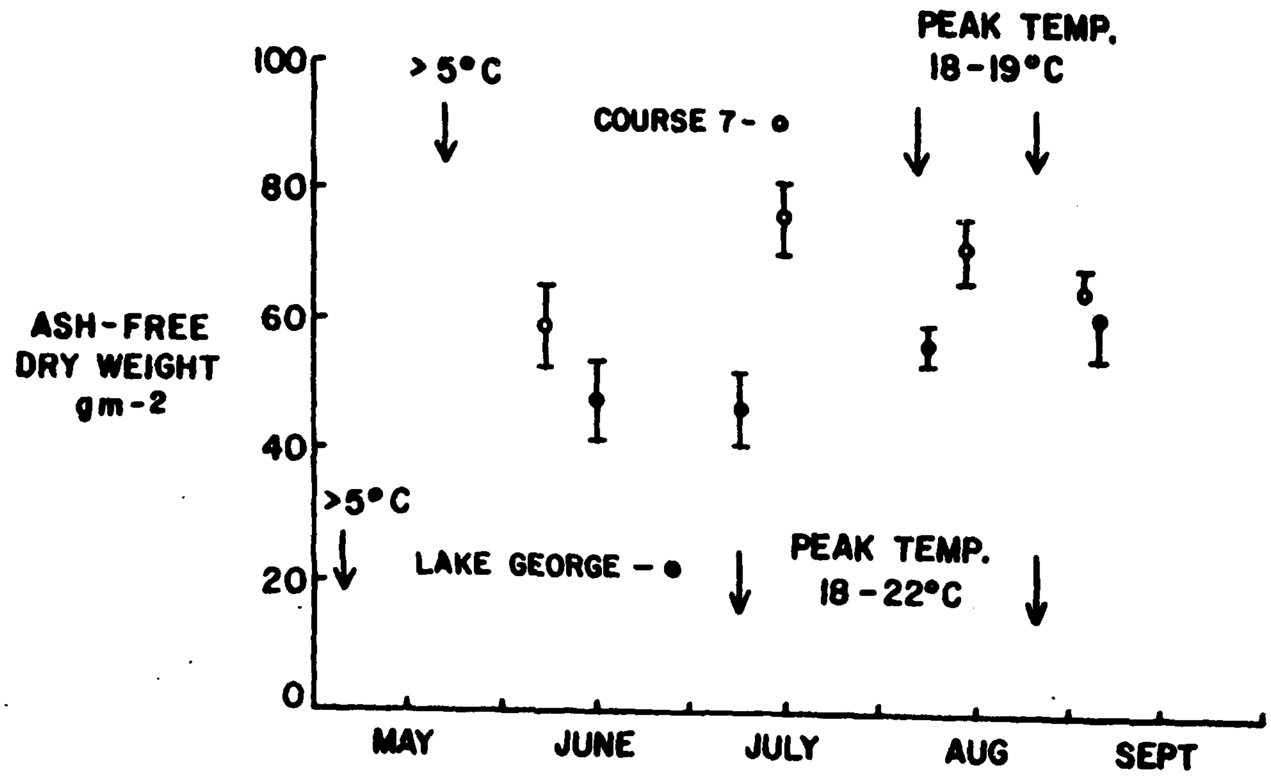


Figure 24. Biomass of the quillwort, *Isoetes riparia*, in beds located on transects in Course 7 of the Upbound Neebish Channel of the St. Mary's River and in Lake George during 1981. One standard error of means is given. Features of the temperature regimes of the two environments are shown.

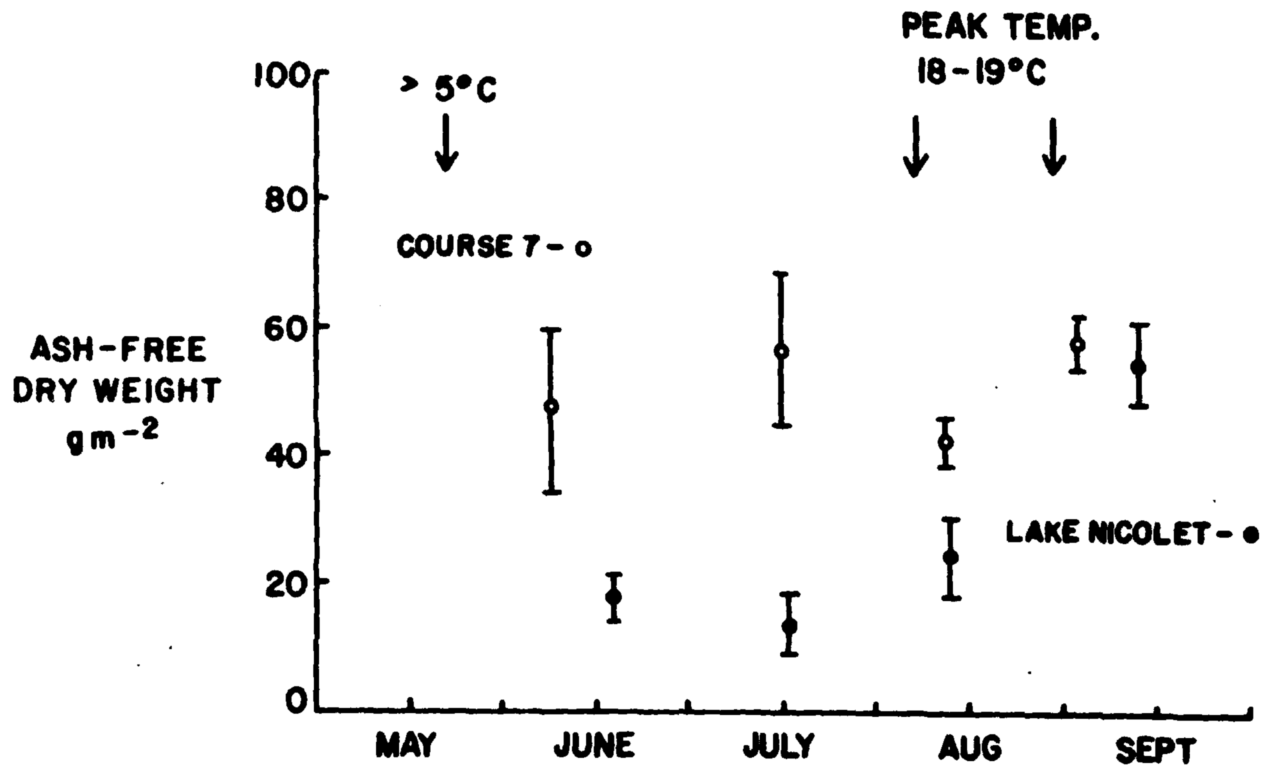


Figure 25. Biomass of charophytes (> 95% *Nitella flexilis*) in beds located on transects in Course 7 of the Upbound Neebish Channel of the St. Mary's River and in Lake Nicolet during 1981. One standard error of means is given. Features of the temperature regime are shown for these sites.

macroscopic filamentous algae develop, in the relatively nutrient-poor reaches of the St. Marys system studied, on the nutrient resources available from degenerating plants that have over-wintered in charophyte beds.

Leaves of Isoetes riparia grew from a compact stem to form rosettes that were scattered over sediments to form nearly monotypic stands on transects in Lake George and along Course 7. In samples collected in June 1981, plants forming biomass given in Figure 24 were large; rosettes stood 5 - 8 cm above the sediments (Tables B3 and B8). These plants had apparently over-wintered. Handling these large plants during the study suggested that this species sluffed old leaves from rosettes, replacing them over time with new growth. Additionally, samples from Lake George after July, and from the transect on Course 7 after August, had many small plants (less than 3 cm height; Tables B3 and B8). In the last one-half of the period of sampling, biomass in beds of I. riparia were made up of older plants that were growing new leaves and sluffing old leaves, and new small plants that were holding their recently grown leaves.

Biomass sampling from beds over intervals of time in the growing season tends not to result in an estimate of growth for charophytes and I. riparia in the St. Marys River. Results of studies in 1981 (Figure 24) show annual maximum biomass of I. riparia can be estimated from samples taken anytime in the growing season; in addition to an estimate of annual maximum biomass, an index of recruitment within beds can be obtained by sampling in August - September. From the discussion above, and the data of Figure 25, annual maximum biomass of charophytes in the St. Marys River would be best estimated by samples taken in the latter part of August or in September.

General procedure for submersed biomass sampling in this study was to identify limits of distinct vegetation types (e.g. charophytes, quillworts, potamogetons), and to collect samples from within these limits. In such an approach, visual inspection of the vegetation and hand collection of samples was the preferred method for determining biomass. During segments of the study, however, low temperature and/or high current velocity made hand-harvesting unsafe and susceptible to increased error of measurement. A PONAR dredge was then used. This dredge was not a suitable device for sampling tall vegetation where upper plant parts were excluded during vertical passage through the vegetation. Because of the low growth habitat of dominant plants in the St. Marys River (2 - 20 cm), they could be captured by the dredge without serious loss. However, the action of the jaws of this dredge was not the same across the area of sediments the dredge enclosed. In particular, the bite of the dredge was more shallow along edges of the quadrat into which the jaws initially moved than in the center of the quadrat. This edge effect was avoided in the hand-harvesting technique.

Hand and PONAR Plant Sampling Comparisons

During 1981, a study was conducted to compare results of the two sampling procedures. Beds of charophytes and Isoetes riparia were chosen in an area of low to moderate current east of Course 7, Upbound Neebish Channel. Data from this work are given in Tables 5 and 6. Means of biomass from hand-collected samples were higher than means from dredge-collected samples for both

Table 5. Statistical comparison of hand-collected and dredge-collected ash-free biomass from an *Isoetes riparia* dominated plant bed along Course 7 of the Upbound Neebish Channel of the St. Marys River; July 27, 1981.

Sampling Method[1]	Mean Ash-Free Dry Weight g m^{-2} of *Isoetes riparia* & Others[2,3]	Sample Size (r)	Variance (s^2)	Sums of Squares (SS)
Hand	65.06	25	269.62	6470.79
Dredge	56.63	25	209.09	5018.20

1. Hand sampler enclosed an area of 0.051 m^2; Ponar dredge had an area of 0.052 m^2.

2. Other species taken were *Myriophyllum tenellum*, *Myriophyllum* sp., and *Potamogeton robbinsii* with total weight of 2.5 g m^{-2} for hand sampling and 1.8 g m^{-2} for dredge sampling.

3. Student's t-test for equality of means with equal variances and equal sample size (Gill 1978) $t = (Y_1 - Y_2) / \{(1/r^1 + 1/r^2)(SS_1 + SS_2) / (r_1 + r_2 - 2)\}^{1/2} = 1.47$; $P < .10$.

Table 6. Statistical comparison of hand-collected and dredge-collected ash-free biomass from a charophyte dominated plant bed along Course 7 of the Upbound Neebish Channel of the St. Marys River; July 23, 1981.

Sampling Method[1]	Mean Ash-Free Dry Weight $g\ m^{-2}$ of *Nitella flexilis* & others[2,3]	Sample Size (r)	Variance (s^2)	Sums of Squares (SS)
Hand	22.97	25	62.57	1501.63
Dredge	19.78	25	55.80	1339.22

1. Hand sampler enclosed an area of 0.051 m^2; Ponar dredge had an area of 0.052 m^2.

2. Other species taken were *Elodea canadensis*, *Isoetes riparia*, *Myriophyllum* sp. and *Potamogeton* sp. with total weight of 2.5 $g\ m^{-2}$ for hand sampling and 1.3 $g\ m^{-2}$ for dredge sampling.

3. Student's t-test for equality of means with equal variances and equal sample size (Gill 1978) $t = (Y_1 - Y_2) / \{(1/r^1 + 1/r^2)(SS_1 + SS_2) / (r_1 + r_2 - 2)^{\frac{1}{2}}\} = 1.47$; $P < .20$.

charophyte and I. riparia beds. Students' t-test (Gill 1978) was applicable to these data. The hypothesis that means resulting from the two procedures were equal could be rejected with at least 90% confidence for the I. riparia bed, and with 80% confidence for the bed of charophytes. The larger difference between hand and dredge collections in the quillwort bed than in the charophyte bed was explained by the action of the dredge on the dominant plant types. Underwater observation of the dredge as it closed on samples suggested that it did not sample the relatively high biomass in rootstocks of I. riparia as completely as the hand-sampling procedure. Rootstocks were left in the sediments near edges of the dredge over which jaws moved while closing. Loss of biomass by this action was expected higher in Isoetes than in charophyte stands; rhizoidal biomass in charophytes was a lower percentage of total biomass than was the rootstock biomass of I. riparia. Both hand-harvesting and dredge sampling were adequate for making collections without loss of collected material in the process. The difference in results was taken as due to the fact that the effective sampling area of the dredge was somewhat smaller than the area of the device with the jaws open (effective area smaller than 0.052 m^2).

Biomass estimates obtained by dredging were converted in all portions of this study to hand-sampling equivalents to provide a consistent base for comparison of results. Dredge-obtained biomass was multiplied by proportions of mean hand biomass/mean dredge biomass taken from data in Tables 5 and 6. This proportion for I. riparia beds was 1.150; for charophyte beds it was 1.161.

Annual Variation in Standing Crops of Submersed Plants

In 1979, beds of submersed vegetation were described for locations along the edge of the Upbound Neebish Navigation Channel (Liston et al. 1980). Data were obtained in 1981 on between-year variation in bed locations, species composition, and biomass. Table B10 contains the information gathered in 1981.

A comparison of data in Table B10 with that of 1979 showed that plant beds were found in the same locations in both years. No shifts in dominant species occurred between years; the charophytes, Nitella flexilis and Chara globularis, were dominant in both years. Elodea canadensis, and the charophyte, Tolypella intricata, were found sporadically in samples in each year. Regarding the latter, examination of material collected in 1981, and review of voucher specimens from 1979, suggested that this plant (T. intricata) was a species of Chara.

Biomass data for the transects used in the 1979 - 1981 comparative study are summarized in Table 7. The distribution of samples taken each year within depth contours is shown in the Table. The manner in which samples from each navigation course are clustered within contours tends to be a function of the shape of the bottom of the river beneath surface transects along which sampling points were evenly distributed. For example, the portion of Lake Munuscong adjacent to the channel-edge of Course 9 was deep with an abrupt rise on the transects between 5 m and 7 m; samples tended to be clustered in the 7 m and 3 - 5 m intervals at that location. Such clustering patterns of samples are evident in the data of Table 5 for other courses used in this study as well. There appears to be a trend in mean bed biomass of each course toward an increase in 1981 over 1979. However, from the characteristic variance in

Table 7. **Comparison of charophyte biomass (ash-free g m^{-2}) collected from submersed beds along the Upbound Neebish Channel in 1979 and 1981. Number of samples is given in parentheses; biomass estimates in the table are means of these[1].**

Depth Interval m	Course 5		Course 7		Course 9	
	1979	1981	1979	1981	1979	1981
3 - 4	28.4 (3)	27.4 (2)	- (0)	- (0)	14.2 (1)	34.1 (3)
4 - 5	65.2 (6)	29.5 (4)	60.9 (2)	93.3 (2)	19.4 (4)	36.1 (3)
5 - 6	- (0)	61.5 (1)	0.2 (2)	62.1 (3)	- (0)	0 (1)
6 - 7	0.6 (1)	61.5 (1)	46.4 (1)	0.3 (1)	- (0)	0 (1)
>7	- (0)	nil[2] (2)	0 (5)	0 (4)	nil[2] (5)	0 (2)
Plant Bed Means	31.4	45.0	35.8	51.9	16.7	35.1

1. Samples for this comparison were collected from transects between channel markers 72 - 70 and *68 - 66 in Course 5, 38 - 36 and 32 - 30 in Course 7, and 16 - 14 and 14 - 12 in Course 9*; collections were made 15 July - 8 August, 1979 and on 15 August, 1981.

2. Plant fragments in these samples had weights too small (<0.08 g dry weight) for accurate ash-free weight determination.

samples from charophyte beds along the edge of this channel, such a conclusion is unwarranted. Channel-edge beds of vegetation appeared to be stable in terms of location, species composition, and biomass between years of these measurements.

ICHTHYOPLANKTON

Middle Neebish and Lake George Channels, 1981

A total of 3133 fish larvae were collected in 118 samples from Stations 5, 7 and 9 and Lake George from 9 April through 28 September 1981 (Table 8). Larvae of 16 taxa were collected, with rainbow smelt larvae being the most abundant (70% of the total catch). In general, densities of larvae were greatest in channel collections in late May and early June (see Appendix Tables C1 to C61).

Larvae of nine taxa (alewife, rainbow smelt, Cyprinidae, burbot, trout-perch, yellow perch, logperch, and *Cottus* sp.) were collected in the channel at all stations. Cisco and ninespine stickleback larvae were collected at all stations except 7, and johnny darter larvae were collected at all stations except 5. Lake whitefish and sucker larvae were collected in the channel only at Station 9. Fourhorn sculpin larvae were collected at Stations 5 and 9, and *Lepomis* sp. larvae at Station 5 and in Lake George. Carp larvae were collected offshore only in Lake George. The greatest number of taxa (14) and larvae (1273) were collected at Station 9. The fewest number of taxa were collected at Station 7 (9) and fewest number of larvae (318) were collected at Station 5 (Tables 9 - 12).

Burbot larvae dominated the early spring collections in the Middle Neebish Channel, while rainbow smelt dominated the late spring collections at all stations. Percid larvae (yellow perch, logperch, johnny darter), *Lepomis* sp. and suckers were dominant in early summer, followed by cyprinid and sculpin (*Cottus* sp.) larvae (Appendix D, Tables D1 - D12).

Maximum surface water temperatures in the channel occurred in Lake George, reaching a maximum of 20.5°C on 24 August. Temperatures were lowest at Station 9 where the highest temperature reached was 18°C on 4 August and 24 August (Figures 26 to 29).

Edge of Macrophytes, 1981 (0.5 m net)

A total of 3897 fish larvae were collected in 121 samples along the edge of macrophyte beds in 1981. Larvae of 17 taxa were collected (Table 8), with rainbow smelt representing 69.2% of the total catch. In general larvae were abundant near the edge of macrophyte beds throughout the field season, with a taxonomic succession of larvae being abundant in the collections. Chronologically, burbot, rainbow smelt, percids, catostomids, and cyprinid larvae were abundant at this depth (0.5 - 1.0 m) (Tables D1 - D12).

The greatest number of taxa (14) were collected at Station 7 (Table 10) and the greatest number of larvae (2454) were collected at Station 9 (Table 11).

Table 8. Total number of fish larvae, by gear type, collected in the St. Marys River during 9 April through 28 September 1981.

Gear	Pull Net		0.5 m Net		1.0 m Net		All Gear	
No. Collections	139		121		118		378	
Volume filtered (m^3)	463.6		6,685.8		14,214.8		21,364.2	
Taxon	Number	% of Catch	Number	% of Catch	Number	% of Catch	Number	% of Total Catch
Cisco	16	1.0	51	1.3	9	0.3	76	0.9
Lake whitefish	45	2.9	12	0.3	1	<0.1	58	0.7
Alewife	0	0.0	11	0.3	86	2.7	97	1.1
Rainbow smelt	21	1.3	2,696	69.2	2,190	69.9	4,907	57.1
Central mudminnow	0	0.0	2	0.1	0	0.0	2	<0.1
Carp	54	3.4	122	3.1	33	1.1	209	2.4
Cyprinidae	507	32.3	350	9.0	24	0.8	881	10.3
White sucker	11	0.7	0	0.0	0	0.0	11	0.1
Catostomidae	183	11.7	56	1.4	354	11.3	593	6.9
Burbot	4	0.4	185	4.8	250	8.0	439	5.1
Trout-perch	3	0.1	8	0.2	17	0.5	28	0.3
Ninespine stickleback	0	0.0	3	0.2	12	0.4	15	0.2
Rock bass	1	0.1	4	0.1	0	0.0	5	0.1
Lepomis sp.	362	23.1	29	0.7	3	0.1	394	4.6
Johnny darter	44	2.8	45	1.2	33	1.1	122	1.4
Yellow perch	160	10.2	146	3.8	12	0.4	318	3.7
Logperch	157	10.0	156	4.0	47	1.5	360	4.2
Cottus sp.	1	0.1	20	0.5	57	1.8	78	0.9
Fourhorn sculpin	0	0.0	0	0.0	5	0.2	5	0.1
Unidentifiable	0	0.0	1	<0.1	0	0.0	1	<0.1
TOTAL	1,569		3,897		3,133		8,599	

Table 9. Total number of fish larvae collected in pull net (PN), 0.5 m, and 1.0 m net collections at Station 5, St. Marys River, 9 April through 28 September, 1981.

Gear	PN		0.5 m N		1.0 m N	
No. Collections	46		38		36	
Volume filtered (m^3)	137.0		2084.4		4550.5	
Taxon	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch
Cisco	8	2	6	1	4	1
Lake whitefish	41	12	4	<1	0	0
Alewife	0	0	0	0	1	<1
Rainbow smelt	7	2	111	23	270	85
Central mudminnow	0	0	1	<1	0	0
Carp	53	16	107	22	0	0
Cyprinidae	14	4	97	20	1	<1
White sucker	7	2	0	0	0	0
Catostomidae	2	<1	0	0	0	0
Burbot	0	0	17	3	30	9
Trout-perch	2	<1	4	<1	1	<1
Ninespine stickleback	0	0	0	0	1	<1
Rock bass	0	0	0	0	0	0
Lepomis sp.	76	22	17	3	1	<1
Johnny darter	2	<1	8	2	0	0
Yellow perch	98	29	91	19	3	<1
Logperch	29	9	28	6	2	<1
Cottus sp.	0	0	0	0	2	<1
Fourhorn sculpin	0	0	0	0	2	<1
TOTAL	339		491		318	

Table 10. Total number of fish larvae collected in pull net (PN), 0.5 m net, and 1.0 m net collections at Station 7, St. Marys River, 9 April through 28 September, 1981.

Gear	PN		0.5 m N		1.0 m N	
No. Collections	31		28		28	
Volume filtered (m^3)	113.9		1557.2		3341.7	
Taxon	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch
Cisco	2	<1	16	3	0	0
Lake whitefish	2	<1	1	<1	0	0
Alewife	0	0	2	<1	2	<1
Rainbow smelt	3	1	340	69	699	90
Central mudminnow	0	0	1	<1	0	0
Carp	0	0	0	0	0	0
Cyprinidae	82	29	9	2	2	<1
White sucker	0	0	0	0	0	0
Catostomidae	15	5	1	<1	0	0
Burbot	1	<1	70	14	52	7
Trout-perch	1	<1	2	<1	2	<1
Ninespine stickleback	0	0	3	<1	0	0
Rock bass	0	0	0	0	0	0
Lepomis sp.	161	56	8	2	0	0
Johnny darter	3	1	6	1	1	<1
Yellow perch	5	2	18	4	4	<1
Logperch	9	3	4	<1	10	1
Cottus sp.	1	<1	12	2	1	<1
Fourhorn sculpin	0	0	0	0	0	0
TOTAL	285		493		773	

Table 11. Total number of fish larvae collected in pull net (PN), 0.5 m, and 1.0 m net collections at Station 9, St. Marys River, 9 April through 28 September, 1981.

Gear	PN		0.5 m N		1.0 m N	
No. Collections	31		27		28	
Volume filtered (m^3)	104.2		1569.1		3309.9	
Taxon	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch
Cisco	6	2	29	1	2	<1
Lake whitefish	2	<1	7	<1	1	<1
Alewife	0	0	2	<1	7	<1
Rainbow smelt	11	3	2123	87	646	51
Central mudminnow	0	0	0	0	0	0
Carp	1	<1	1	<1	0	0
Cyprinidae	15	4	14	<1	4	<1
White sucker	0	0	0	0	0	0
Catostomidae	157	39	55	2	354	28
Burbot	3	<1	93	4	149	12
Trout-perch	0	0	2	<1	10	<1
Ninespine stickleback	0	0	0	0	2	<1
Rock bass	0	0	0	0	0	0
Lepomis sp.	91	23	2	<1	0	0
Johnny darter	36	9	15	<1	15	1
Yellow perch	14	4	19	<1	2	<1
Logperch	62	16	84	3	28	2
Cottus sp.	0	0	8	<1	50	4
Fourhorn sculpin	0	0	0	0	3	<1
TOTAL	398		2454		1273	

Table 12. Total number of fish larvae collected in pull net (PN), 0.5 m, and 1.0 m net collections in Lake George, St. Marys River, 9 April through 28 September, 1981.

Gear	PN		0.5 m N		1.0 m N	
No. Collections	31		28		26	
Volume filtered (m^3)	108.5		1475.1		3012.7	
Taxon	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch
Cisco	0	0	0	0	3	<1
Lake whitefish	0	0	0	0	0	0
Alewife	0	0	7	2	76	10
Rainbow smelt	0	0	122	27	575	75
Central mudminnow	0	0	0	0	0	0
Carp	0	0	14	3	33	4
Cyprinidae	396	72	230	50	17	2
White sucker	4	<1	0	0	0	0
Catostomidae	9	2	0	0	0	0
Burbot	0	0	5	1	19	2
Trout-perch	0	0	0	0	4	<1
Ninespine stickleback	0	0	0	0	9	1
Rock bass	1	<1	4	<1	0	0
Lepomis sp.	34	5	2	<1	2	<1
Johnny darter	3	<1	16	3	17	2
Yellow perch	43	8	18	4	3	<1
Logperch	57	10	40	9	7	<1
Cottus sp.	0	0	0	0	4	<1
Fourhorn sculpin	0	0	0	0	0	0
TOTAL	547		458		769	

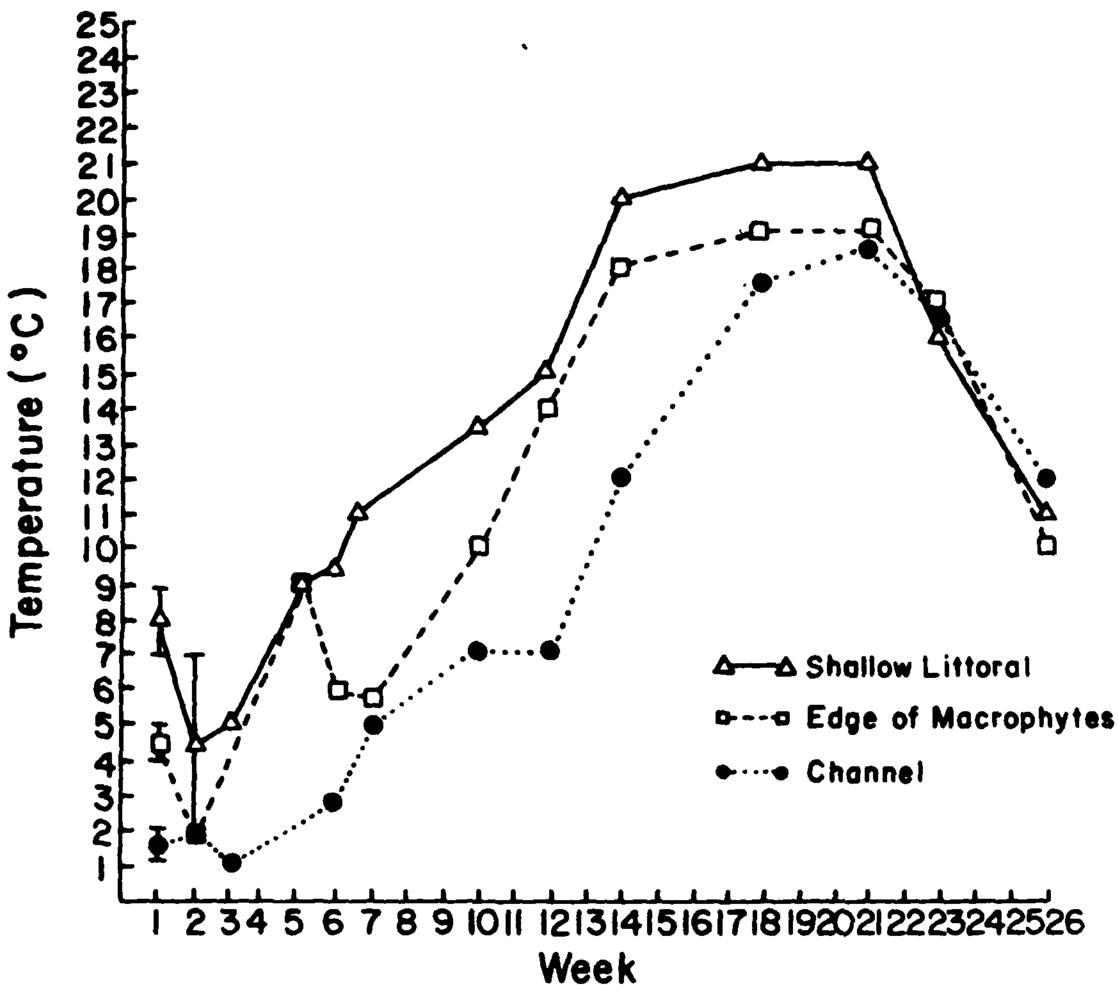


Figure 26. Water temperature at larval fish sampling sites of station 5, St. Mary's River, 1981.

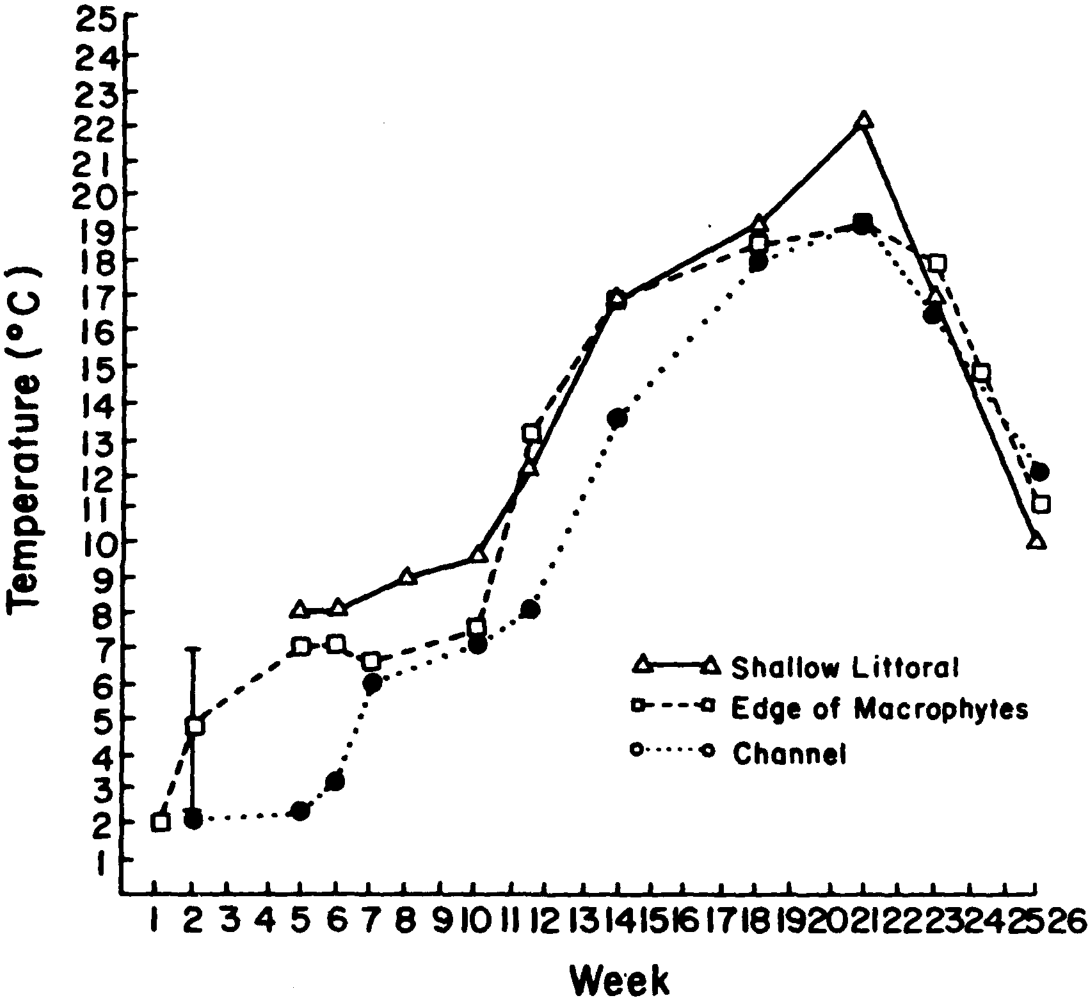


Figure 27. Water temperatures at larval fish sampling sites of station 7, St. Mary's River, 1981.

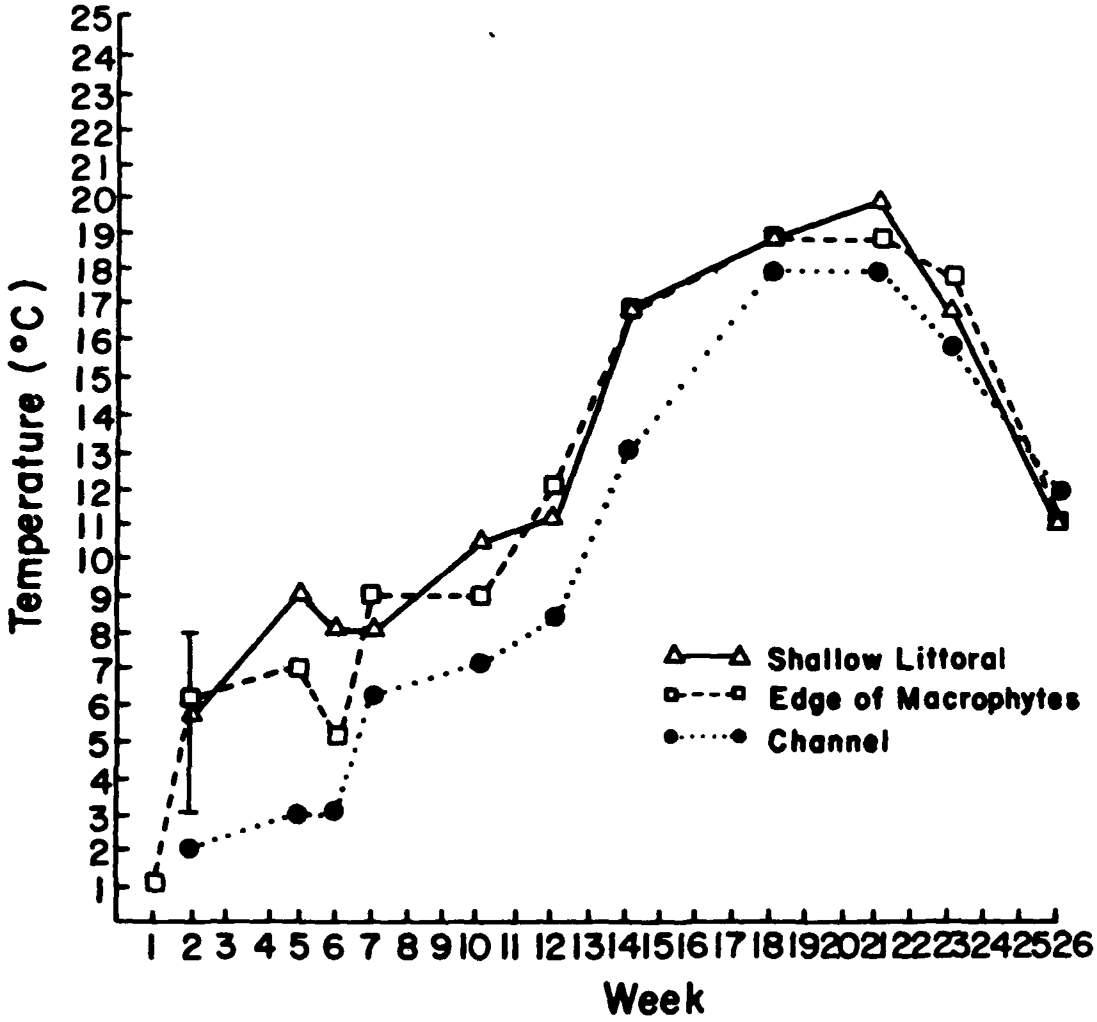


Figure 28. Water temperature at larval fish sampling sites of station 9, St. Mary's River, 1981.

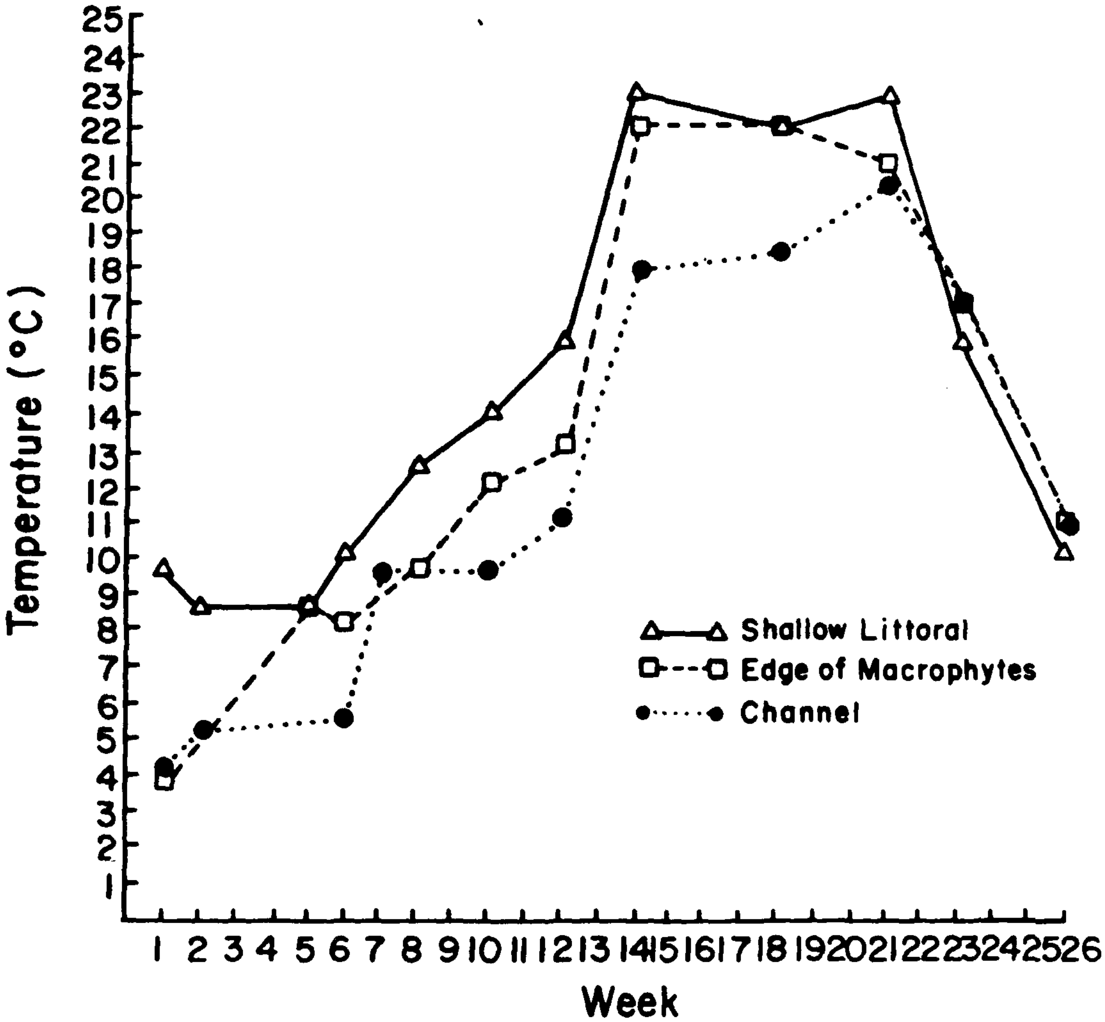


Figure 29. Water temperature at larval fish sampling sites of Lake George, St. Mary's River, 1981.

Rainbow smelt, cyprinid, burbot, johnny darter, yellow perch, logperch, and Lepomis sp. larvae were collected at all stations. Cisco, lake whitefish and trout-perch were collected in littoral zones of Stations 5, 7 and 9, but these species were absent from the littoral zone of Lake George. Alewife larvae were collected at all stations except 5, and carp were collected at all stations except 7. Sucker and sculpin (Cottus sp.) larvae were collected at Stations 7 and 9. Ninespine stickleback larvae were collected only at Station 7, and rock bass were collected only in Lake George (Tables 9 - 12).

Density of larvae was greatest in 0.5 m net collections at all stations in early June. The highest density of larvae (1559/100 m^3) occurred in Station 9 collections on June 9, with rainbow smelt comprising 99% of the catch on this date (Table D1). In July, percid larvae (johnny darter, logperch), Lepomis sp., carp, and other cyprinids were abundant.

Maximum night surface water temperature (22°C) occurred at this depth in Lake George in mid-August (Figure 29). Maximum temperatures of 19°C occurred in the littoral zones of Stations 5, 7 and 9 at the same time (Figures 26, 27, and 28).

Shallow Littoral Zone, 1981 (Pull Net)

A total of 1569 fish larvae were collected in 139 pull net collections at sites within emergent and submerged vegetation in 1981. Larvae of 15 taxa were collected, with the greatest number of taxa (11) being collected at Stations 5 and 7. The greatest abundance of larvae was collected in Lake George where larvae of 8 taxa were represented (Tables 8 - 12). Larvae were abundant in pull net collections in June, July and early August (Tables D1 - D12), with maximum density (4487/100 m^3) in night collections at Station 9 on 7 July 1981. Sucker larvae accounted for 79% of the total catch on this date. High density of carp larvae (2413/100 m^3) was also collected at Station 5 on this date. Maximum density of cyprinid larvae (4314/100 m^3) occurred in Lake George in the 4 August collections.

Larvae of six taxa (cyprinids, suckers, johnny darter, yellow perch, logperch and Lepomis sp.) were collected at all stations. Cisco, lake whitefish and rainbow smelt were collected in the littoral zones of Stations 5, 7 and 9, while rock bass larvae were collected only in Lake George. Carp were collected at Stations 5 and 9, burbot were collected at Stations 7 and 9, and trout-perch at Stations 5 and 7. Sculpin (Cottus sp.) larvae were collected in pull nets only at Station 7 (Tables D1 - D12).

Maximum night surface water temperatures of 23°C were recorded in August in the shallow littoral of Lake George. In the shallow littoral zone of the Middle Neebish Channel, maximum night surface temperatures of 21, 22, and 20°C were reached at Stations 5, 7 and 9, respectively (Figures 26 through 29).

Coregonid Larvae, Spatial and Temporal Occurrence, 1981

In 1981, as in 1980, an effort was made in April and May following ice-out, to collect coregonid (cisco and lake whitefish) larvae in accessible shallow littoral areas using a pull net, and the 0.5 m and 1.0 m push nets

(Liston et al. 1980). A total of 74 cisco and 58 lake whitefish larvae were collected in day and night collections in April and in night collections in May. During these 2 months, a total of 75 pull net, fifty-eight 0.5 m net and forty-eight 1.0 m net samples were collected.

The majority of the lake whitefish larvae (71%) were collected in the shallow littoral zone at Station 5 (Table D12), while cisco larvae were abundant in the shallow littoral zones at Stations 5 and 9 (Table D11). Few coregonid larvae were collected in Lake George with any gear type. Peak density of cisco larvae occurred in night pull net collections at Station 5 on 20 April (50/100 m^3). Maximum density of lake whitefish larvae (238/100 m^3) also occurred at this station on this date.

In addition to April and May, cisco larvae were collected in a 0.5 m net at Station 9 on 9 June, a 1.0 m net at Station 5 on 23 June, and in a 1.0 m net in Lake George on 7 July.

Other Taxa, Spatial and Temporal Occurrence, 1981

Of the twenty taxa collected in 1981, seven taxa (alewife, rainbow smelt, carp, cyprinids, suckers, burbot, and johnny darter) accounted individually for 1% or greater of the total larval catch (Table 8). For most of these species, as well as for logperch, unidentified percids, and yellow perch, abundance (density) of larvae was highest in collections from shallow littoral stations in emergent and submersed vegetation (Tables D1 to D12). The most abundant or most frequently encountered taxa are discussed below.

Burbot larvae were present in collections from 9 April through 23 June, with peak density (26/100 m^3) in 1.0 m net collections at Station 9 on 4 May. Larvae were taken infrequently in pull net collections and only at Stations 7 and 9 (Table D4).

Rainbow smelt larvae were taken from 14 May through 24 August, however, densities peaked in the 9 June collections at all stations (Table D1). Larvae were most abundant in the shallow areas in 0.5 m net collections at Station 9.

Cyprinid larvae were collected from 9 June through 24 August, with abundance being consistently highest in Lake George, particularly in pull net collections (Table D3). Water temperatures in the shallow littoral area in Lake George were consistently higher than in the shallow littoral areas inshore from the Middle Neebish Channel (Figures 26 to 29) and may help to explain the greater abundance of cyprinids.

Sucker larvae were collected on 7 and 20 July, primarily in pull net collections (Table D3). Sucker larvae were most abundant (3564/100 m^3) in the shallow littoral zone collections at Station 9 on 7 July. Sucker larvae were also collected in channel collections at this station on this date.

Johnny darter larvae were collected from 23 June through 4 August, and were most abundant in 20 July pull net collections at Station 9 (702/100 m^3) (Table D8).

Yellow perch larvae were collected from 21 May through 4 August, and were most abundant in pull net collections at all stations (Table D7). Peak density (1448/100 m^3) occurred in pull net collections at Station 5 on 9 June. Few yellow perch larvae were present in channel collections at any station.

Logperch larvae were present in collections from 9 June through 24 August, with peak densities (744 and 651/100 m^3) in pull net collections at Station 9 and Lake George, respectively. Few logperch larvae were collected offshore in channel collections (Table D6).

Lepomis sp. larvae were abundant in pull net collections at all stations from 23 June through 24 August. Overall, abundance at Station 7 was the greatest, with a peak density (911/100 m^3) occurring in the 4 August pull net collections (Table D5).

Carp larvae were collected from 23 June through 4 August, at all stations except Station 7. Peak abundance of carp larvae occurred at Station 5 in the 7 July pull net collections (1109/100 m^3) (Table D9).

Alewife larvae were collected from 20 July through 24 August and again on 28 September. Density was greatest in the 21 July channel collections in Lake George (26/100 m^3) (Table D10).

Other taxa, such as central mudminnow, white sucker, ninespine stickleback, rock bass, sculpin larvae (Cottus sp.) and fourhorn sculpin were either taken infrequently, in small numbers or only on one occasion, owing to short periods of vulnerability to capture or, more likely, their occurrence in habitats not sampled by the collecting gear.

Comparison of 1979, 1980, and 1981 Collections

1.0 m Net Collections. Fish larvae of 23 taxa were collected in the St. Marys River in 1979, 1980 and 1981 (Table 13). Modifications in both sampling stations and gear over the three years complicates strict comparisons among years, as does the rather abbreviated field season in 1980. In general, species composition varied little from year to year. However, greater numbers of larvae were collected as the study progressed, as sampling included more shallow littoral areas suspected of harboring concentrations of larvae. Densities of larvae are considerably higher in the inshore areas compared to offshore channel sites.

Aside from possible annual variation in larval abundance, several other factors may influence the numbers of larvae collected and confound interpretation of data from year to year. These include actual time of collection of sample, habitat characteristics (vegetation, substrate, current patterns, etc.) particular to an individual station, water temperature, frequency of sampling, and behavior of larvae.

In 1979 and 1981, collections were made from April through September in the navigation channels at Stations 5, 7 and 9 and are suitable for comparison (Table 14). At all stations in both years rainbow smelt larvae were the most abundant taxa collected. Burbot larvae were also taken in relatively large

Table 13. Occurrence of fish larvae in pull net, 0.5 m, and 1.0 m net collections in 1979, 1980, 1981.

Year	1981			1980			1979
Gear	PN	0.5 m N	1.0 m N	PN	0.5 m N	1.0 m N	1.0 m N
<u>Taxon</u>							
<u>Lampetra</u> sp.							X
Cisco	X	X	X	X			X
Lake whitefish	X	X	X	X			
Alewife		X	X		X	X	X
Rainbow smelt	X	X	X		X	X	X
Central mudminnow		X					
Carp	X	X				X	X
Cyprinidae	X	X	X		X		X
White sucker	X				X		
<u>Moxostoma</u> sp.					X		
Catostomidae	X	X			X		X
Burbot	X	X	X				X
Trout-perch	X	X	X		X	X	X
Ninespine stickleback		X	X		X		X
Rock bass	X	X					
<u>Lepomis</u> sp.	X	X	X		X	X	X
Johnny darter	X	X			X	X	X
Yellow perch	X	X	X		X		X
Logperch	X	X	X		X	X	X
Walleye							X
<u>Cottus</u> sp.	X	X	X		X	X	X
Fourhorn sculpin			X				X
Unidentifiable			X				

Table 14. Comparison of number of fish larvae collected in 1.0 m net samples in the navigation channels at Stations 5, 7 and 9 during April through September, St. Marys River, 1979 and 1981.

Station	5				7				9				All Stations			
Year	1979		1981		1979		1981		1979		1981		1979		1981	
No. Collections	27		36		26		28		18		28		71		92	
Volume filtered (m^3)	2737.5		4550.5		2760.6		3341.7		2528.3		3309.9					
Taxon	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Lampetra sp.	0	0	0	0	3	<1	0	0	2	<1	0	0	5	1	0	0
Cisco	0	0	4	1	0	0	0	0	0	0	2	<1	0	0	6	<1
Lake whitefish	0	0	0	0	0	0	0	0	0	0	1	<1	0	0	1	<1
Alewife	44	12	1	<1	34	10	2	<1	25	12	7	<1	103	11	10	<1
Rainbow smelt	251	71	270	85	238	68	699	90	129	60	646	51	618	67	1,615	68
Cyprinidae	4	1	1	<1	5	1	2	<1	0	0	4	<1	9	1	7	<1
Catostomidae	2	<1	0	0	0	0	0	0	6	3	354	28	8	1	354	15
Burbot	29	8	30	9	35	10	52	7	17	8	149	12	81	9	231	10
Trout-perch	3	<1	1	<1	3	<1	2	<1	5	2	10	<1	11	1	13	1
Ninespine stickleback	0	0	1	<1	0	0	0	0	0	0	2	<1	0	0	3	<1
Johnny darter	3	<1	0	0	0	0	0	0	2	<1	15	1	5	1	15	1
Yellow perch	8	2	3	<1	19	5	4	<1	3	1	2	<1	30	3	9	<1
Logperch	2	<1	2	<1	4	1	10	1	6	3	28	2	12	1	40	2
Walleye	2	<1	0	0	0	0	0	0	0	0	0	0	2	<1	0	0
Lepomis sp.	4	1	1	<1	4	1	0	0	12	6	0	0	20	2	1	0
Cottus sp.	1	<1	2	<1	7	2	1	<1	7	3	50	4	15	2	53	2
Fourhorn sculpin	0	0	2	<1	0	0	0	0	0	0	3	<1	0	0	5	<1
TOTAL	353		318		352		773		214		1,273		919		2,363	

numbers at all stations in both years. The major differences in species abundance were the few numbers of alewife larvae collected in 1981 compared to 1979, and the large number of catostomid larvae from 1981 samples compared to 1979. Alewife were the second most abundant taxa in 1979, but accounted for 1% or less of the catch in 1981. Catostomid larvae comprised 15% of all larvae in 1981 compared to about 1% in 1979. A possible explanation is that the sampling regime in 1981 was interrupted by mechanical boat problems allowing more time between samples in July and August (i.e. three weeks instead of two). The importance of timing of sampling is evident when one examines data from individual collections. Often the majority of the specimens of a taxa are collected on one or possibly two sampling dates. On-going 1982 sampling and proposed 1983 collections will provide more opportunity to examine annual changes in percent composition and densities, with relationships to water temperature and other environmental parameters examined.

Samples were collected in the navigation channel in all three years at Stations 7 and 9 during July through September (Tables 15 and 16). At Station 7 in all three years, rainbow smelt larvae dominated the collections during this period, ranging from 59% to 73% of the total catch in 1981 and 1980, respectively. Perch larvae (yellow perch, logperch, johnny darter) and Lepomis sp. were abundant. Alewife comprised 2 - 4% of the total catch during this sampling period in all three years. Differences at Station 9 in abundance of larvae were evident (Table 16). In 1979 and 1980, rainbow smelt were abundant (54 and 21% of the total catch, respectively), while in 1981, sucker larvae comprised 75% of the catch. In addition alewife larvae accounted for 18% of the catch in 1979, and 37% of the catch in 1980, but only 1% in 1981. Sculpin larvae were most numerous in 1981, followed by 1979, but were absent in the 1980 offshore collections.

0.5 m Net Collections. Comparison of species composition and relative abundance of fish larvae in 0.5 m net collections along the edge of macrophyte beds at Stations 7 and 9 is possible among the July through September portion of the 1980 and 1981 field seasons (Tables 15 and 16).

At Station 7, rainbow smelt and alewife larvae were taken in greater numbers in 1980 than in 1981. Cyprinid larvae were abundant (8 - 14% of the total catch) in both years. Yellow perch larvae were collected only in 1981. Sculpin (Cottus sp.) larvae were abundant (16 - 18% of the total catch) in both years at this depth (Table 15).

Similarly, in 0.5 m net collections at Station 9, alewife larvae were abundant (18%) in 1980, but few were taken (<1% of total catch) in 1981. Rainbow smelt were similar in relative abundance, but densities were about three times greater in 1980 compared to 1981. Similarly, cyprinid larvae comprised nearly the same percentage composition both years, although densities were about 3.5 times greater in 1980. Yellow perch were much more abundant in 1980 than 1981, but logperch larval abundance changes were relatively small between years.

Coregonid Larvae (1980 and 1981). In 1980, 51 pull net samples were collected in the shallow littoral zone of the St. Marys River in the vicinity of the Dunbar Research Station. In 1981, 30 pull net collections were made in the

Table 15. Summary of total number of fish larvae collected in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, July through September 1979, 1980, 1981.

Station	7-S				7-C					
Year	1980		1981		1979		1980		1981	
No. Collections	12		12		17		10		12	
Volume filtered (m^3)	804.4		587.7		1924.9		820.8		1391.9	
Taxon	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch
Lampetra sp.	0	0	0	0	3	1	0	0	0	0
Alewife	10	7	2	3	34	2	6	4	2	4
Rainbow smelt	62	46	5	8	139	64	103	73	32	59
Carp	0	0	0	0	0	0	1	<1	0	0
Cyprinidae	11	8	9	14	5	2	0	0	2	4
Catostomidae	1	<1	1	2	0	0	0	0	0	0
Trout-perch	2	1	2	3	3	1	4	3	2	4
Ninespine stickleback	2	1	3	5	0	0	0	0	0	0
Johnny darter	2	1	6	9	0	0	6	4	1	2
Yellow perch	0	0	15	23	19	9	0	0	4	7
Logperch	17	13	4	6	4	2	4	3	10	19
Lepomis sp.	7	5	7	11	4	2	1	<1	0	0
Cottus sp.	21	16	12	18	7	3	17	12	1	2
TOTAL	135		66		218		142		54	

Table 16. Summary of total number of fish larvae collected in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, July through September 1979, 1980, 1981.

Station	9-S				9-C					
Year	1980		1981		1979		1980		1981	
No. Collections	10		12		18		7		12	
Volume filtered (m^3)	638.6		568.5		1987.9		540.0		1490.4	
Taxon	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch	Number	% Total Catch
Alewife	141	18	2	<1	25	18	7	37	7	1
Rainbow smelt	119	15	37	16	74	54	4	21	4	<1
Cyprinidae	56	7	14	6	0	0	0	0	3	<1
White sucker	5	<1	0	0	0	0	0	0	0	0
Moxostoma sp.	1	<1	0	0	0	0	0	0	0	0
Catostomidae	1	<1	55	24	6	4	0	0	354	75
Trout-perch	5	<1	2	<1	5	4	2	11	10	2
Ninespine stickleback	0	0	0	0	0	0	0	0	2	<1
Johnny darter	24	3	15	7	2	1	5	26	15	3
Yellow perch	270	35	6	3	1	<1	0	0	1	<1
Logperch	129	17	84	37	6	4	1	5	28	6
Lepomis sp.	5	<1	2	<1	12	9	0	0	0	0
Cottus sp.	23	3	8	4	7	5	0	0	50	11
TOTAL	779		225		138		19		474	

shallow littoral area inshore from Station 5 of the Middle Neebish Channel. In 1981, the greatest density of cisco larvae (103/100 m^3) occurred in a night collection on 20 April, as did the greatest density of lake whitefish larvae (333/100 m^3). Surface water temperatures on this date were 5°C, however day surface temperatures of 9°C were recorded earlier in April (Figure 26). Eight cisco larvae and 41 lake whitefish were present in pull net collections at Station 5 in 1981. In 1980, 17 cisco and 46 lake whitefish larvae were present in pull net collections from a contiguous littoral area. Highest density of cisco larvae in 1980 occurred on 25 April (193/100 m^3). Highest density of lake whitefish larvae occurred on 27 April (250/100 m^3). Surface water temperatures were not recorded on either date. Coregonid larvae appear to be more abundant in night collections, however, the presence of ice floes in early April makes night sampling extremely hazardous.

JUVENILE AND ADULT FISH

Gill Nets

Winter, 1981. A total of 310 fish composed of 12 species were taken in 43 bottom gill net sets from late January through March in Navigation Courses 5 and 7 in 1981 (Table 17). White sucker was found to comprise 42.5% of the catch, with cisco contributing 35.5%. Lesser represented species were yellow perch (6.5%), northern pike (4.5%), and burbot (4.5%). Differences in species distribution were observed both among and between sample sites in 1981.

Cisco dominated catches from Navigation Course 5 (percent of total number 53.8; Table 18). Most cisco were captured at site 1 (Figure 5), with peak catches occurring in March. The majority of cisco taken were captured in that portion of the net nearest the ship channel margin. White sucker and burbot were secondary and tertiary dominants in catches contributing 26.9 and 12.9%, respectively. No trends in distribution of these species were apparent.

Gill net collections at Navigation Course 7 were dominated by white sucker (49.3%), cisco (27.6%), yellow perch (10.1%), and northern pike (6.0%) (Table 19). Cisco were captured in slightly higher numbers in the off-channel net, while white sucker, yellow perch and northern pike were captured primarily in the nearshore net. Peak catches of white sucker were noted in February while cisco collection modes occurred in March.

Fish lengths from winter collections of white sucker ranged from 195 - 525 mm total length (TL) with frequency peaks centered at the 390, 420, 440 and 480 mm intervals (Table 20). Cisco lengths ranged from 213 - 452 mm TL. Eighty-one percent of the cisco were within 363 - 452 mm TL while 16.8% were <318 mm TL with nearly all of these captured in sets at Navigation Course 7. Yellow perch lengths ranged from 161 to 300 mm TL with the mode centered at 230 mm TL (Table 20). Northern pike ranged from 301 to 860 mm TL with the mode centered at 620 mm TL. Total lengths of burbot ranged from 425 to 648 mm with the frequency distribution centered at 519 mm TL. Too few fish were captured to indicate any peaks in the sample. Size of remaining winter-collected fish were as follows: smelt, 134 - 167 mm; lake whitefish, 486 - 593 mm; round whitefish,

Table 17. Summary of all gill net collections taken during January through March at Navigation Courses 5 and 7 in the St. Marys River, 1981 (N = 43).

Species	Total Number	Percent of Total Number	Catch Per Effort	Total Weight (g)	Percent of Total Weight
White sucker	132	42.5	3.1	114,717	50.3
Cisco	110	35.5	2.6	62,622	27.4
Yellow perch	22	6.5	0.5	5,240	2.3
Northern pike	14	4.5	0.3	17,784	7.8
Burbot	14	4.5	0.3	18,830	8.2
Smelt	9	2.6	0.2	171	<0.1
Lake whitefish	4	1.2	0.1	6,080	2.7
Round whitefish	1	0.3	<0.1	490	0.2
Walleye	1	0.3	<0.1	1,220	0.5
Rainbow trout	1	0.3	<0.1	740	0.3
Chinook salmon	1	0.3	<0.1	300	0.1
Spottail shiner	1	0.3	<0.1	12	<0.1
TOTAL	310			228,206	100.0

Table 18. Summary of all gill net collections taken during January through March at Navigation Course 5 in the St. Marys River, 1981 (N = 21).

Species	Total Number	Percent of Total Number	Catch Per Effort	Total Weight (g)	Percent of Total Weight
Cisco	50	53.8	2.4	33,313	41.9
White sucker	25	26.9	1.2	24,610	31.0
Burbot	12	12.9	0.6	16,510	20.8
Smelt	2	2.1	<0.1	3,850	4.8
Lake whitefish	2	2.1	<0.1	490	0.6
Northern pike	1	1.0	<0.1	32	<0.1
Round whitefish	1	1.0	<0.1	608	0.8
TOTAL	93			79,413	100.0

Table 19. Summary of all gill net collections taken during January through March at Navigation Course 7 in the St. Marys River, 1981 (N = 22).

Species	Total Number	Percent of Total Number	Catch Per Effort	Total Weight (g)	Percent of Total Weight
White sucker	107	49.3	4.9	90,107	61.5
Cisco	60	27.6	2.7	29,309	20.0
Yellow perch	22	10.1	1.0	5,240	3.6
Northern pike	13	6.0	0.6	17,176	11.7
Smelt	7	3.2	0.3	139	<0.1
Lake whitefish	2	0.9	0.1	2,230	1.5
Burbot	2	0.9	0.1	2,320	1.6
Rainbow trout	1	0.5	<0.1	740	0.5
Chinook salmon	1	0.5	<0.1	300	0.2
Spottail shiner	1	0.5	<0.1	12	<0.1
Walleye	1	0.5	<0.1	1,220	0.8
TOTAL	217	100.0		146,473	100.0

Table 20. Length frequency composition of major species taken during winter with bottom gill nets from Navigation Courses 5 and 7, St. Marys River, 1980 and 1981.

Yellow perch			Northern pike			White sucker			Cisco		
Midpoint of Length Interval (mm)	% Frequency		Midpoint of Length Interval (mm)	% Frequency		Midpoint of Length Interval (mm)	% Frequency		Midpoint of Length Interval (mm)	% Frequency	
	1980	1981		1980	1981		1980	1981		1980	1981
170	6.7	4.5	320	0.0	7.1	210	0.0	0.9	220	0.0	4.6
190	13.3	0.0	360	0.0	7.1	240	5.0	0.0	235	5.3	3.6
210	40.0	4.5	400	5.0	0.0	270	5.0	2.7	250	0.0	2.7
230	20.0	27.3	440	0.0	0.0	300	0.0	0.0	265	10.5	0.9
250	6.7	36.4	480	0.0	7.1	330	0.0	2.7	280	1.8	0.0
270	13.3	13.64	520	35.0	14.3	360	0.0	1.8	295	1.8	2.7
290	0.0	13.64	560	20.0	7.1	390	10.0	13.4	310	5.3	3.6
			600	0.0	14.3	420	35.0	44.6	325	7.0	0.9
			640	25.0	14.3	450	30.0	16.1	340	5.3	0.9
			680	10.0	14.3	480	15.0	17.0	355	8.8	0.0
			720	0.0	0.0	510	0.0	0.9	370	14.0	6.4
			760	5.0	14.3				385	21.0	23.6
									400	10.5	25.4
									415	7.0	18.2
									430	0.0	5.4
									445	1.8	0.9
Number of Fish	15	22		20	14		20	112		57	110

377 mm; walleye 482 mm; rainbow trout, 434 mm; chinook salmon, 315 mm; spottail shiner, 115 mm.

Winter, 1980 vs. 1981. Data on catch per effort (CPE) and length frequencies from winter, 1980, were compared with data from winter, 1981, although Navigation Course 5 was not sampled in 1980, and a site nearer Lake Munuscong was sampled in 1980 but not 1981 (Liston et al. 1981). Station depths and proximity to shorelines and ship channels was similar, however, between the two years.

Comparison of 1980 and 1981 winter CPE for all stations and species generally indicated greater CPE values in 1981 (Figure 30). The combined catch of white sucker and cisco comprised the bulk of the catch with order of dominance reversed between years. Catches of white sucker and cisco increased considerably in 1981, while CPE of all other species was 0.5 or less for both years. Eleven species were taken in 1980, while 12 species were captured in 1981. Species appearing in 1980 but not 1981 included carp, trout-perch and longnose gar. Species appearing in 1981 but absent in 1980 included lake whitefish, round whitefish, chinook salmon and rainbow trout.

Seventy-eight percent of the 1981 catch consisted of white sucker and cisco compared to 54% for these species in 1980 (Figure 31). Greatest catch composition increase in 1981 was evidenced by white sucker, increasing from 14.3% in 1980 to 42.5% in 1981. Northern pike, cisco, and yellow perch all declined in percent composition in 1981. The decline of walleye to 0.3% of the 1981 catch contrasted against the 1980 value of 9.3% was also noteworthy.

Length frequency peaks for white sucker collected during winter in 1980 and 1981 were similar with most fish falling between 376 - 495 mm TL (Table 20). A larger range was evident in the 1981 sample, perhaps as a consequence of the increased number of fish taken that year. The majority of cisco fell between 363 and 422 mm TL for both years (Table 20), however, a greater percentage of individuals were 258 mm or smaller in 1981. Cisco tended to fall more into the extremes of the length range in 1981, while middle length intervals (257 - 377 mm) contained more individuals in 1980 (Table 20). Yellow perch lengths were distributed differently in 1980 and 1981 (Table 20). In 1980, frequencies were consistently greater at smaller lengths (160 - 220 mm) while the reverse was true for length intervals beginning at 220 mm in 1981. Winter captured northern pike were primarily between 501 and 700 mm TL during 1980 and 1981. However, proportionately more individuals were smaller than 500 mm and larger than 700 mm in 1981 compared to 1980 (Table 20). Walleye captured during winter, 1980 ranged broadly between the 301 to the 640 mm TL intervals with no peaks discernable. A single walleye taken in 1981 was 482 mm. Burbot total lengths ranged from 410 - 648 mm for 15 fish captured in 1981 with mean length calculated at 519 mm TL. A mean length of 346 mm was recorded for four burbot sampled in 1980.

Open Water, Navigation Courses 5, 7 and 9, 1981. A total of 1,742 fish representing 26 species were captured in 78 net sets from Navigation Courses 5, 7 and 9 during open water seasons, 1981. Dominant species were white sucker (25.5%), cisco (21.9%), yellow perch (17.2%), northern pike (11.9%), rock bass (7.6%), and walleye (7.6%) (Table 21).

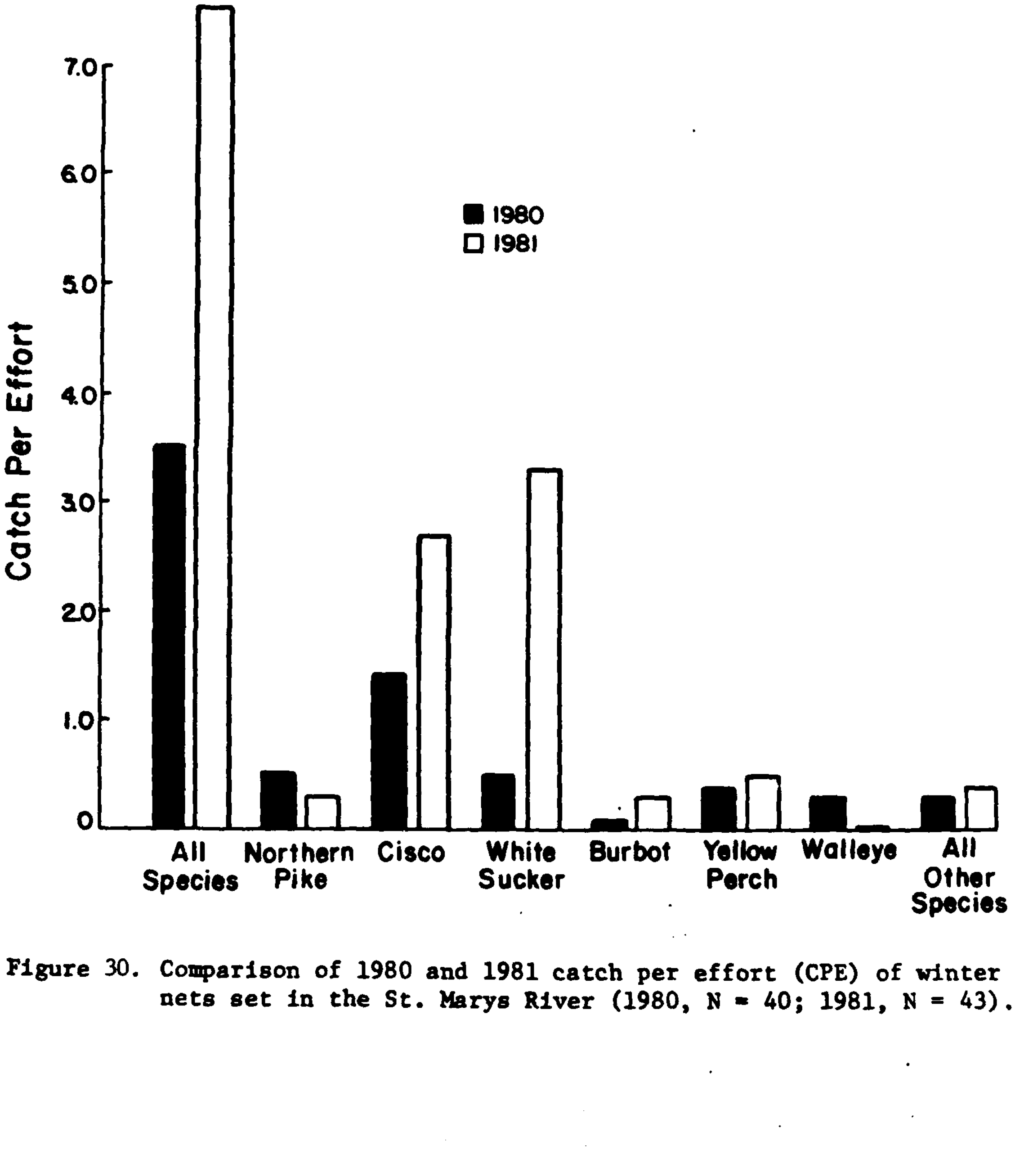


Figure 30. Comparison of 1980 and 1981 catch per effort (CPE) of winter gill nets set in the St. Marys River (1980, N = 40; 1981, N = 43).

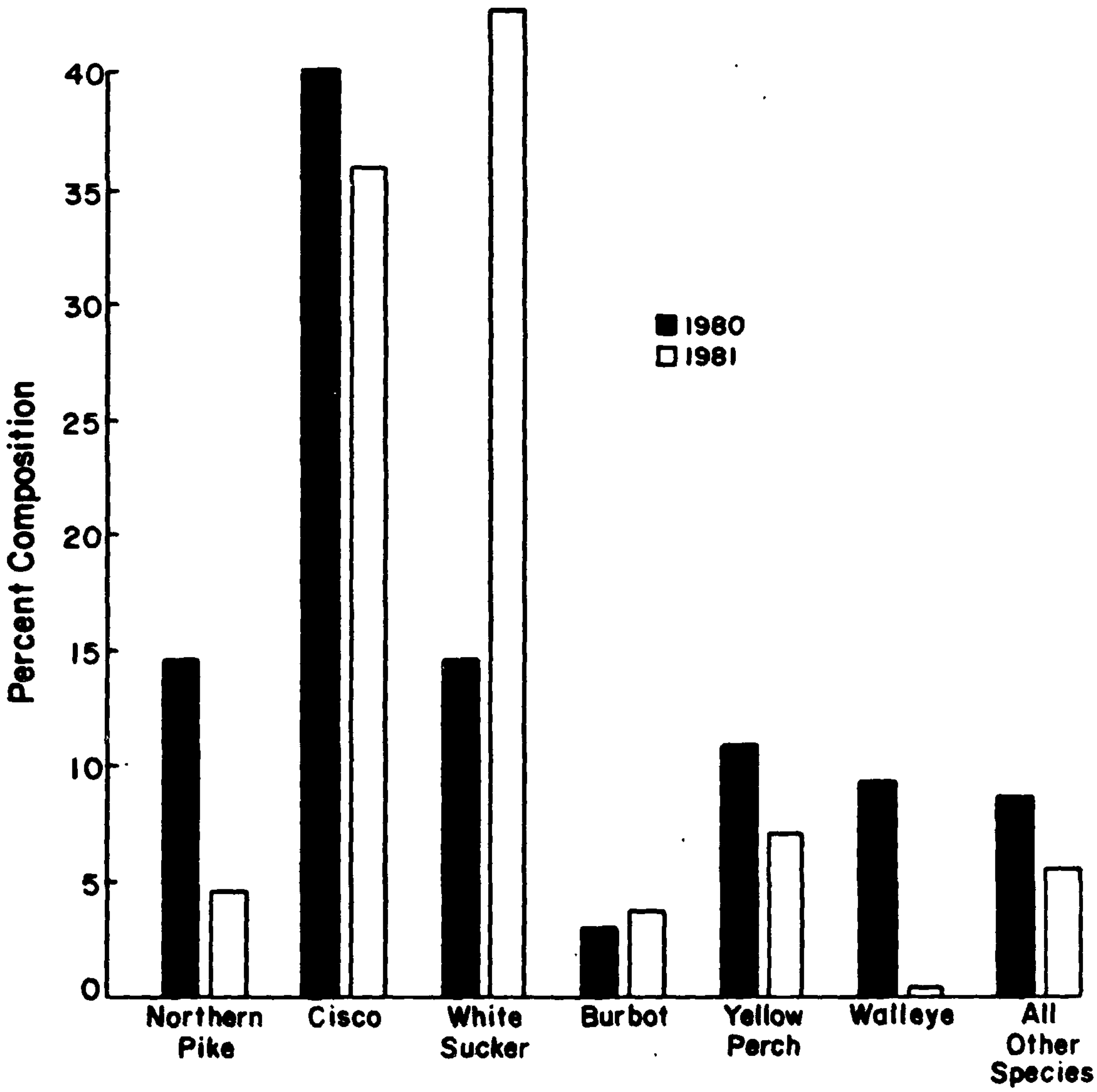


Figure 31. Percentage composition of winter gill net collections taken during 1980 and 1981, St. Marys River.

Table 21. Summary of all gill net collections taken during April through November at Navigation Courses 5, 7 and 9 in the St. Marys River, 1981 (N = 78).

Species	Total Number	Percent of Total Number	Catch per Effort	Total Weight (g)	Percent of Total Weight
White sucker	455	25.5	5.7	359,707	34.8
Cisco	381	21.9	4.9	188,567	18.2
Yellow perch	300	17.2	3.8	57,167	5.5
Northern pike	207	11.9	2.6	179,063	17.3
Rock bass	132	7.6	1.7	31,960	3.1
Walleye	132	7.6	1.7	92,840	9.0
Pink salmon	26	1.5	0.3	24,862	2.4
Smelt	20	1.1	0.3	364	<0.1
Brown bullhead	19	0.9	0.2	5,378	0.5
Spottail shiner	14	0.8	0.2	261	<0.1
Shorthead redhorse	13	0.7	0.2	15,146	1.5
Silver redhorse	10	0.6	0.1	25,080	2.4
Trout-perch	9	0.5	0.1	137	<0.1
Chinook salmon	6	0.3	0.1	24,618	2.4
Alewife	6	0.3	0.1	266	<0.1
Emerald shiner	4	0.3	<0.1	45	<0.1
Carp	5	0.3	<0.1	13,350	1.3
Channel catfish	3	0.2	<0.1	1,729	0.2
Pumpkinseed	3	0.2	<0.1	556	0.1
Lake whitefish	3	0.2	<0.1	4,730	0.5
Burbot	2	0.1	<0.1	3,500	0.3
Longnose gar	1	0.1	<0.1	1,330	0.1
Rainbow trout	1	0.1	<0.1	1,910	0.2
Coho salmon	1	0.1	<0.1	1,750	0.2
Smallmouth bass	1	0.1	<0.1	600	0.1
Rosyface shiner	1	0.1	<0.1	12	<0.1
TOTAL	1,742	100.0	22.3	1,034,928	100.0

Spring samples were dominated by white sucker, northern pike, cisco, and yellow perch. Species frequently captured during summer sampling were white sucker, northern pike, and yellow perch. Cisco and walleye were occasionally captured in high numbers, primarily during July. Fall sample dominants were white sucker, northern pike, yellow perch, and rock bass. November collections contained significant numbers of cisco, lake whitefish and pink salmon.

Catch per effort for all species from both nearshore and near-channel was greatest in Navigation Course 7 (Figure 32). The nearshore nets yielded higher CPE values (all species combined) at all stations than did nets set nearest the ship channel.

Nearshore catches of white sucker were comparable among the three navigation courses, and were consistently greater than near-channel catches. The smallest overall CPE occurred in near-channel waters at Course 9 (Figure 32). Cisco was taken mainly in Course 7, and nearshore nets generally produced more fish. Yellow perch collections were distributed among stations and depths nearly identical to cisco collections (Figure 32). Northern pike were concentrated at Course 9 with nearly equal numbers collected at nearshore and near-channel sites for all stations. Rock bass were rare at Course 7 and were commonly taken at Course 9. Walleye was the only major species generally concentrated at Course 5, where nearshore nets caught the majority of individuals.

Length frequencies for white sucker collected during open water 1981 ranged from 196 - 596 mm TL (Table 22). The mode was centered at 421 mm TL. Roughly 74% of the catch was composed of fish between 376 and 495 mm TL. Cisco ranged in length from 123 - 482 mm TL. Eighty-two percent fell within 318 - 437 mm TL with the distribution mode located at 413 mm TL. Total lengths of yellow perch ranged from 81 - 420 mm TL. Most perch (89%) fell within 161 - 340 mm, with the peak centered at 230 mm. Northern pike ranged from 301 - 860 mm TL (Table 23). Roughly 26% of the pike catch was in the interval centered on the mode of 480 mm TL. Nearly 88% of the total catch was contained within the interval from 380 - 620 mm TL. Rock bass total lengths ranged from 111 - 370 mm. Most rock bass (86%) fell within 171 - 270 mm TL with the peak at 245 mm. Walleye ranged from 241 - 660 mm TL with the peak centered at 430 mm (Table 23). Forty-six percent of the catch was contained within the 401 - 540 mm TL interval.

<u>Open Water, Lake George.</u> A total of 28 gill net samples from Lake George collected 652 fish represented by 22 species (Table 24). Nearly 73% of the catch consisted of white sucker (30.5%), northern pike (21.8%), and yellow perch (20.2%). Rock bass, walleye, and cisco were common in samples. White sucker and northern pike together comprised roughly 70% of the total weight of the catch. Walleye contributed about 8.4% by weight (Table 24).

Northern pike, yellow perch, and white sucker dominated catches at the inception of sampling in spring. These species continued to be common in June samples. Rock bass and walleye were collected frequently in July. Small numbers of pink salmon and cisco were taken in fall collections.

Highest catch per effort for all species was recorded in the near channel net (Figure 33). CPE broken down by major species indicated all fish to occur more frequently in the near channel collections with the exception of rock bass.

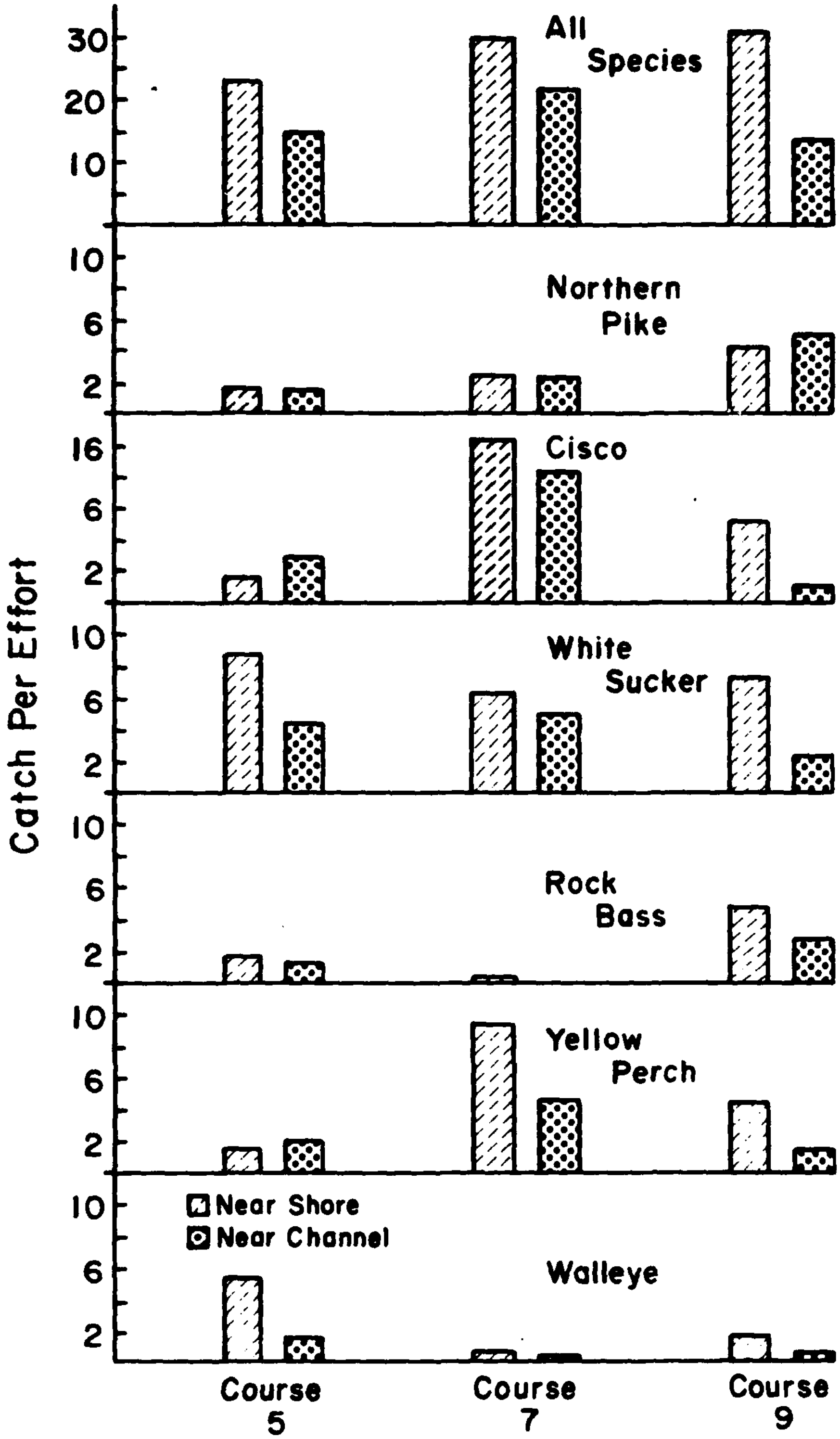


Figure 32. Comparison of catch per effort of major species collected with gill nets during open water months (April through November) in Navigation Courses 5, 7 and 9, St. Marys River, 1981.

Table 22. Comparison of length frequencies (%) of white sucker, cisco, and yellow perch collected during open water seasons in 1980 and 1981 by bottom gill nets, Navigation Courses 5, 7 and 9, St. Marys River.

White sucker			Cisco			Yellow perch		
Midpoint of Length Interval (mm)	1980	1981	Midpoint of Length Interval (mm)	1980	1981	Midpoint of Length Interval (mm)	1980	1981
90	0.5	0.0	100	1.4	0.0	70	0.9	0.0
.			115	2.8	0.0	90	2.6	3.6
.			130	1.9	1.1	110	2.6	3.6
210	0.5	2.0	145	0.5	0.0	130	1.8	0.4
240	2.4	1.1	160	0.0	0.0	150	0.9	0.4
270	5.3	1.1	175	0.0	0.0	170	6.1	5.8
300	4.4	4.6	190	0.0	0.0	190	17.5	15.2
330	5.8	7.8	205	0.5	0.0	210	16.7	9.9
360	7.8	6.3	220	2.4	0.7	230	17.5	14.8
390	11.6	14.1	235	3.8	0.4	250	12.3	14.3
420	32.5	28.7	250	2.4	0.0	270	10.5	12.1
450	20.9	22.0	265	1.9	2.0	290	3.5	6.7
480	6.3	9.1	280	6.6	5.5	310	5.3	5.4
510	1.5	2.8	295	10.9	1.8	330	1.8	4.9
540	0.0		310	9.0	2.9	350	0.0	2.2
570	0.0	0.4	325	3.3	5.9	370	0.0	0.0
.			340	2.4	11.8	390	0.0	0.0
.			355	5.7	10.3	410	0.0	0.4
720	0.0	0.0	370	7.1	10.7			
			385	13.3	11.8			
			400	12.8	12.1			
			415	8.1	12.9			
			430	1.9	7.0			
			445	0.5	1.5			
			460	0.5	0.4			
			475	0.5	0.7			

Table 23. Comparison of length frequencies (%) of northern pike, rock bass and walleye collected during open water seasons in 1980 and 1981 by bottom gill nets, Navigation Courses 5, 7 and 9, St. Marys River.

Northern pike			Rock bass			Walleye		
Midpoint of Length Interval (mm)	1980	1981	Midpoint of Length Interval (mm)	1980	1981	Midpoint of Length Interval (mm)	1980	1981
200	1.3	0.0	75	1.6	0.0	210	2.1	0.0
•			•			230	2.1	0.0
•			•					
•			•			250	8.5	4.9
280	1.3	0.0	115	0.0	0.8	270	8.5	2.4
320	1.3	1.0	125	1.6	0.8	290	10.6	8.5
360	0.0	1.6	135	6.2	3.0	310	4.3	4.9
400	12.0	5.8	145	1.6	0.0	330	4.3	7.3
440	13.3	14.1	155	4.7	4.5	350	8.5	3.7
480	18.7	25.7	165	6.2	1.5	370	14.9	8.5
520	14.7	23.0	175	6.2	3.8	390	10.6	3.7
560	14.7	12.0	185	10.9	6.8	410	6.4	4.9
600	6.7	7.3	195	10.9	14.4	430	2.1	11.0
640	4.0	3.1	205	14.1	9.8	450	0.0	2.4
680	6.7	2.1	215	6.2	6.8	470	2.1	8.5
720	2.7	2.1	225	12.5	7.6	490	4.3	7.3
760	0.0	0.0	235	3.1	10.6	510	4.3	6.1
800	0.0	1.0	245	7.8	15.9	530	4.3	6.1
840	1.3	1.0	255	1.6	6.8	550	2.1	1.2
880	0.0	0.0	265	1.6	3.8	570	0.0	1.2
920	1.3	0.0	275	1.6	1.5	590	0.0	2.4
			285	1.6	0.8	610	0.0	1.2
			295	0.0	0.0	630	0.0	2.4
			•			650	0.0	1.2
			•					
			•					
			365	0.0	0.8			

Table 24. Summary of all gill net collections taken during April through November from Lake George in the St. Marys River, 1981 (N = 28).

Species	Total Number	Percent of Total Number	Catch per Effort	Total Weight (g)	Percent of Total Weight
White sucker	199	30.5	7.1	177,162	43.0
Northern pike	142	21.8	5.1	107,746	26.2
Yellow perch	132	20.2	4.7	20,076	4.9
Rock bass	45	6.9	1.6	11,036	2.7
Walleye	25	3.8	0.9	34,597	8.4
Cisco	21	3.2	0.8	8,885	2.2
Spottail shiner	17	2.6	0.6	180	<0.1
Longnose sucker	16	2.4	0.6	13,812	3.4
Silver redhorse	10	1.5	0.4	18,156	4.4
Smelt	8	1.2	0.3	183	<0.1
Channel catfish	6	0.9	0.2	4,792	1.2
Pink salmon	5	0.8	0.2	5,288	1.3
Rosyface shiner	5	0.8	0.2	51	<0.1
Brown bullhead	4	0.6	0.1	908	0.2
Shorthead redhorse	4	0.6	0.1	3,870	0.9
Trout-perch	3	0.5	0.1	34	<0.1
Alewife	3	0.5	0.1	29	<0.1
Smallmouth bass	3	0.5	0.1	812	0.2
Mottled sculpin	1	0.2	<0.1	8	<0.1
Carp	1	0.2	<0.1	3,440	0.8
Pumpkinseed	1	0.2	<0.1	112	<0.1
Chinook salmon	1	0.2	<0.1	870	0.2
TOTAL	652	100.0	23.2	412,047	100.0

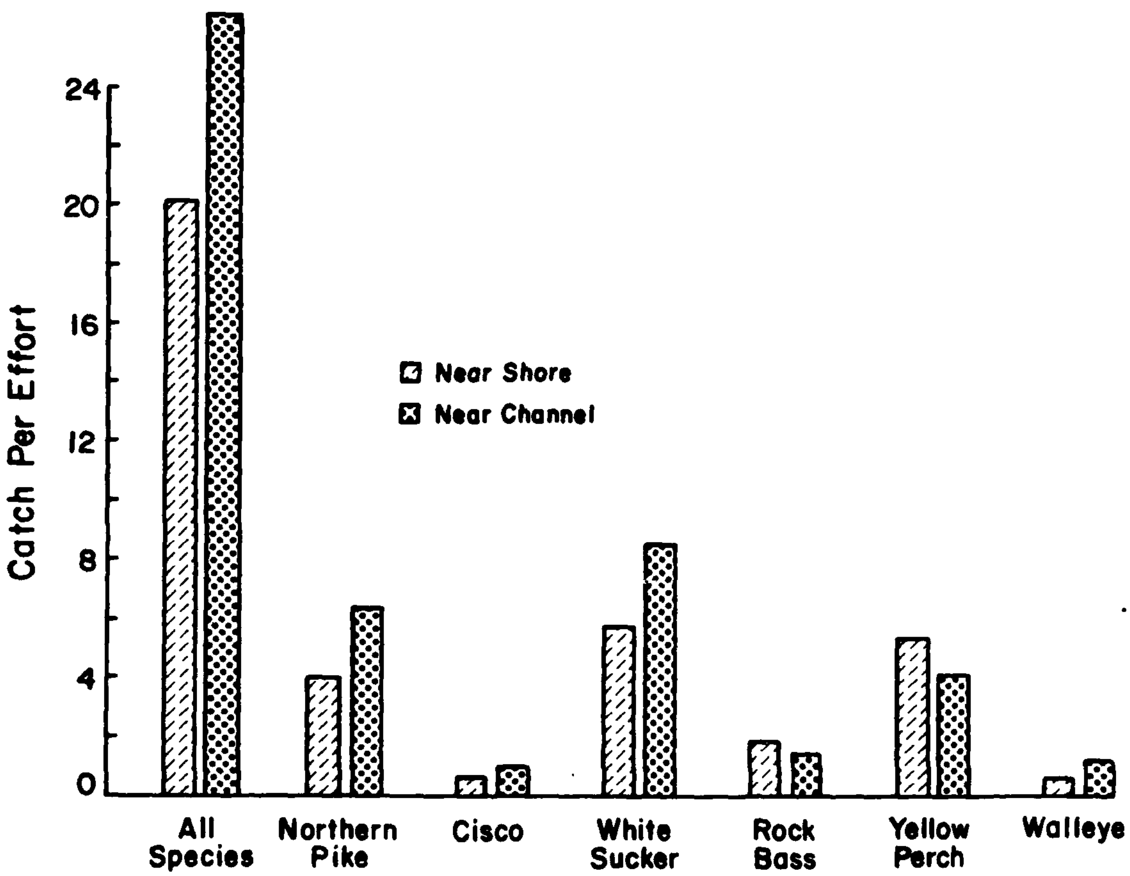


Figure 33. Catch per effort of major species collected with gill nets during open water months (April through November) in Lake George, 1981.

The range in length frequency intervals for white sucker collected in Lake George was 106 - 525 mm TL (Table 25). Nearly seventy-five percent of the catch was between 406 - 495 mm TL with the mode at 420 mm TL. Cisco total lengths ranged from 108 - 437 mm TL. Peaks occurred at 324 and 378 mm TL and 62% of the sample was contained in the interval 318 to 392 mm. Yellow perch ranged from 81 to 350 mm TL. The peak occurred at 183 mm TL, however, 86% of the catch was bounded by the interval 161 - 280 mm TL. Northern pike from Lake George were between 301 and 780 mm TL and about 88% of the catch was contained within the interval 341 - 620 mm (Table 26). Two peaks were noted in the distribution centered at 430 and 540 mm TL. Rock bass total lengths ranged from 131 to 280 mm TL. The mode was centered at 195 mm TL. Roughly 89% of the rock bass catch was within the interval 161 - 260 mm TL. Walleye length frequencies ranged from 341 - 640 mm TL. However, the majority (76%) of the sample was contained within the interval 401 - 560 mm TL with the mode at 470 mm.

<u>Open Water, Navigation Courses 5, 7 and 9, 1980 vs. 1981.</u> Comparison of 1980 - 1981 open water catch-per-effort values revealed that overall CPE declined slightly in 1981 (Figure 34). Comparison of CPE values for single species indicated declines for all species except northern pike, yellow perch, and walleye. Cisco evidenced the greatest decline.

Roughly 48% of the 1980 and 1981 catches consisted of cisco and white sucker with order of dominance and percentage contribution switched between years (Figure 35). Northern pike, white sucker, yellow perch, and walleye all composed a greater percentage of the catch in 1981 as a consequence of the decline in incidence of the minor species in collections.

Length frequency modes for white sucker collected during open water in 1980 - 1981 were similar between years with peaks centered at 390, 420, and 450 mm TL (Table 22). A slightly broader range in the cisco length frequency distribution occurred in 1980. This was a consequence of the collection of more small fish ($<$ 137 mm). Peaks were centered at 340, 355, 370, 385, 400, and 415 mm TL with the bulk of the sample bounded by the interval 333 - 422 mm in 1981. Cisco length frequencies in 1980 indicated the dominance of fish in the 288 - 302 and 378 - 407 mm TL intervals in the catch (Table 22). The bulk of the yellow perch catch was contained within the interval 181 - 280 mm TL during both years. Percentage composition was slightly higher in both tails of the length frequency distribution in 1981. The northern pike length frequencies indicated an interval shift of peaks in the distribution (Table 23). However, the mode was centered at 480 mm TL both years. Rock bass length frequencies exhibited a slightly broader range in 1981. Peaks were noted at 195, 235 and 245 mm TL as compared to peaks at 185, 205 and 225 mm TL in 1980. A slightly broader range for 1981 walleye length frequencies was apparent. The 1980 and 1981 modes were centered at 370 and 430 mm TL, respectively.

<u>Open Water, Lake George vs. Lake Nicolet, 1981.</u> Comparisons of catch per effort for the six major species taken in gill nets is given in Figure 36 for Lake George and Navigation Course 5 (Lake Nicolet). CPE for all species combined was higher in Lake George. This was primarily a function of higher CPE values for northern pike and yellow perch, although all of the major species except cisco and walleye exhibited higher CPE values for Lake George.

Table 25. Comparison of length frequencies (%) of white sucker, cisco and yellow perch collected during open water seasons in 1981 by bottom gill nets, Navigation Course 5 and Lake George, St. Marys River.

White sucker			Cisco			Yellow perch		
Midpoint of Length Interval (mm)	NC 5	LG	Midpoint of Length Interval (mm)	NC 5	LG	Midpoint of Length Interval (mm)	NC 5	LG
120	0.0	0.5	115	0.0	2.9	90	1.8	3.9
150	0.0	0.0	130	0.0	0.0	110	5.4	3.9
180	0.0	0.0	145	0.0	0.0	130	0.0	0.8
210	0.5	0.0	160	0.0	0.0	150	0.0	0.8
240	1.6	3.0	175	0.0	0.0	170	0.0	18.6
270	2.7	1.0	190	0.0	0.0	190	7.1	22.5
300	4.3	0.5	205	0.0	0.0	210	8.9	10.1
330	12.5	4.1	220	0.0	0.0	230	16.1	14.0
360	7.1	6.1	235	1.7	2.9	250	7.1	13.2
390	11.4	8.1	250	0.0	5.9	270	16.1	10.1
420	26.1	34.5	265	0.0	2.9	290	7.1	1.6
450	20.1	27.4	280	0.0	5.9	310	12.5	0.0
480	9.2	12.7	295	0.0	5.9	330	8.9	1.6
510	4.3	4.6	310	1.7	2.9	350	8.9	0.8
			325	1.7	14.7			
			340	13.6	11.8			
			355	8.5	8.8			
			370	15.2	14.7			
			385	16.9	11.8			
			400	16.9	2.9			
			415	11.9	2.9			
			430	10.2	2.9			
			445	1.7	0.0			

Table 26. Comparison of length frequencies (%) of northern pike, rock bass and walleye collected during open water seasons in 1981 by bottom gill nets, Navigation Course 5 and Lake George, St. Marys River.

Northern pike			Rock bass			Walleye		
Midpoint of Length Interval (mm)	NC 5	LG	Midpoint of Length Interval (mm)	NC 5	LG	Midpoint of Length Interval (mm)	NC 5	LG
320	2.3	3.9	135	0.0	2.2	250	2.2	4.0
360	4.6	6.5	145	0.0	0.0	270	2.2	0.0
400	14.0	11.7	155	0.0	2.2	290	6.5	0.0
440	25.6	15.6	165	2.5	6.7	310	4.4	0.0
480	21.0	13.6	175	5.0	11.1	330	6.5	0.0
520	16.3	16.9	185	2.5	8.9	350	4.4	4.0
560	2.3	16.9	195	12.5	15.6	370	10.9	0.0
600	4.6	6.5	205	7.5	8.9	390	6.5	0.0
640	4.6	3.9	215	5.0	6.7	410	4.4	12.0
680	0.0	2.6	225	7.5	11.1	430	13.0	0.0
720	2.3	1.3	235	12.5	6.7	450	2.2	20.0
760	0.0	0.6	245	30.0	6.7	470	13.0	12.0
800	2.3	0.0	255	2.5	6.7	490	8.7	8.0
			265	2.5	4.4	510	4.4	8.0
			275	2.5	2.2	530	4.4	8.0
			285	0.0	0.0	550	2.2	8.0
			.			570	2.2	4.0
			.			590	2.2	4.0
			365	2.5	0.0	610	0.0	4.0
						630	0.0	4.0

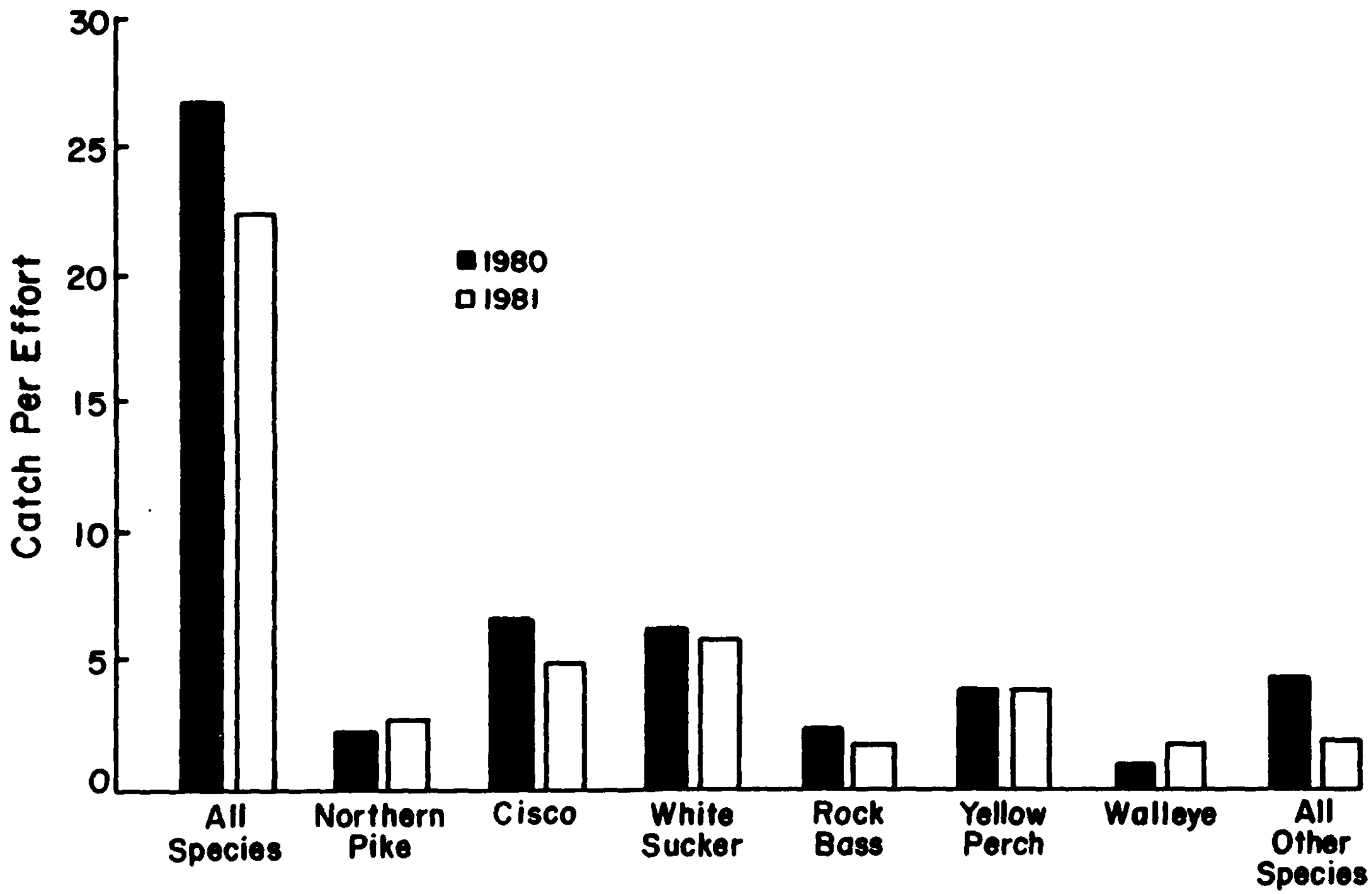


Figure 34. Comparison of catch per effort of major species collected with gill nets during open water months from Navigation Courses 5, 7 and 9, St. Marys River, 1980 vs. 1981.

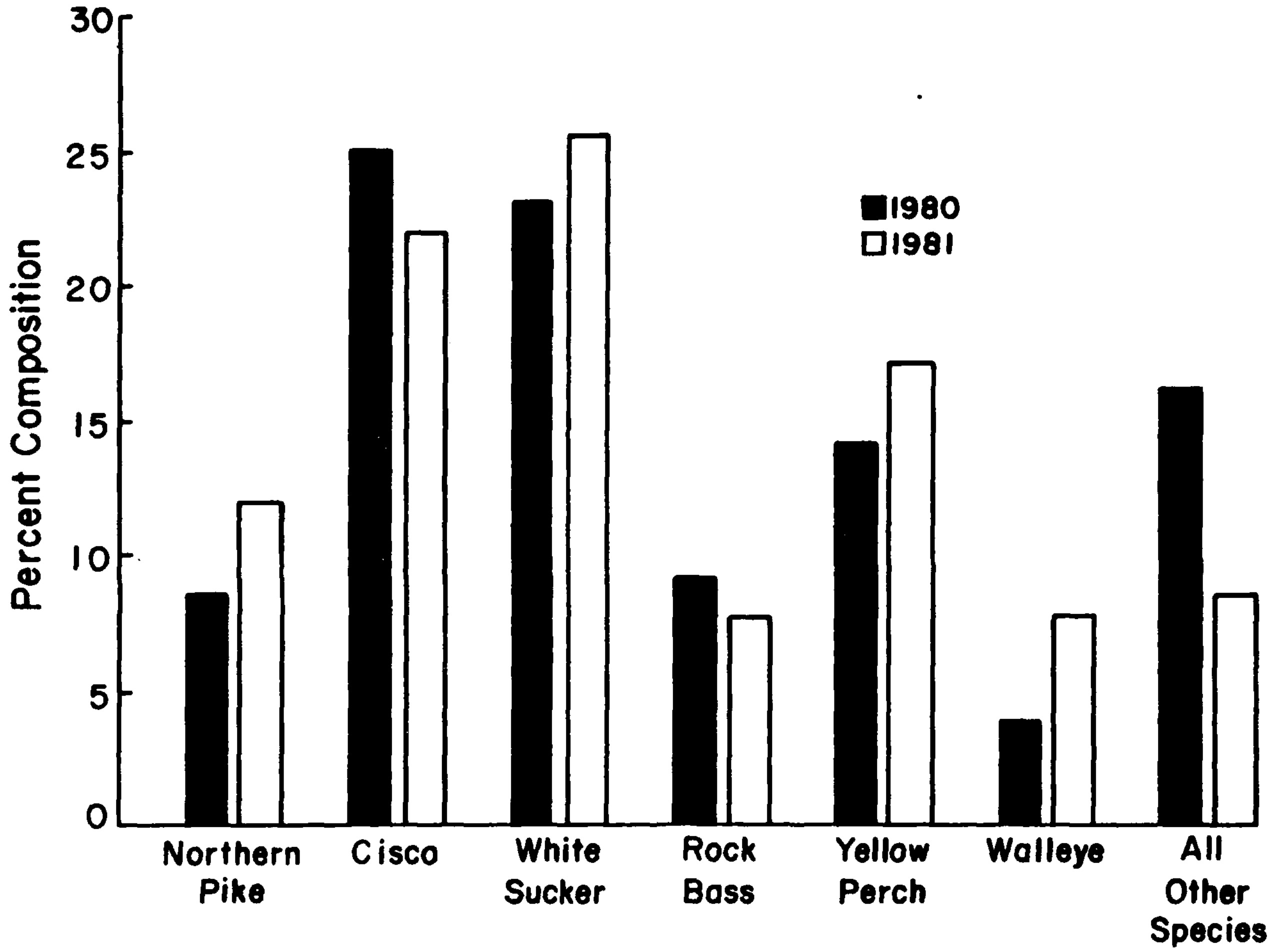


Figure 35. Comparison of percent composition comprised by major species in open water gill net collections taken from Navigation Courses 5, 7 and 9, St. Marys River, 1980 vs. 1981.

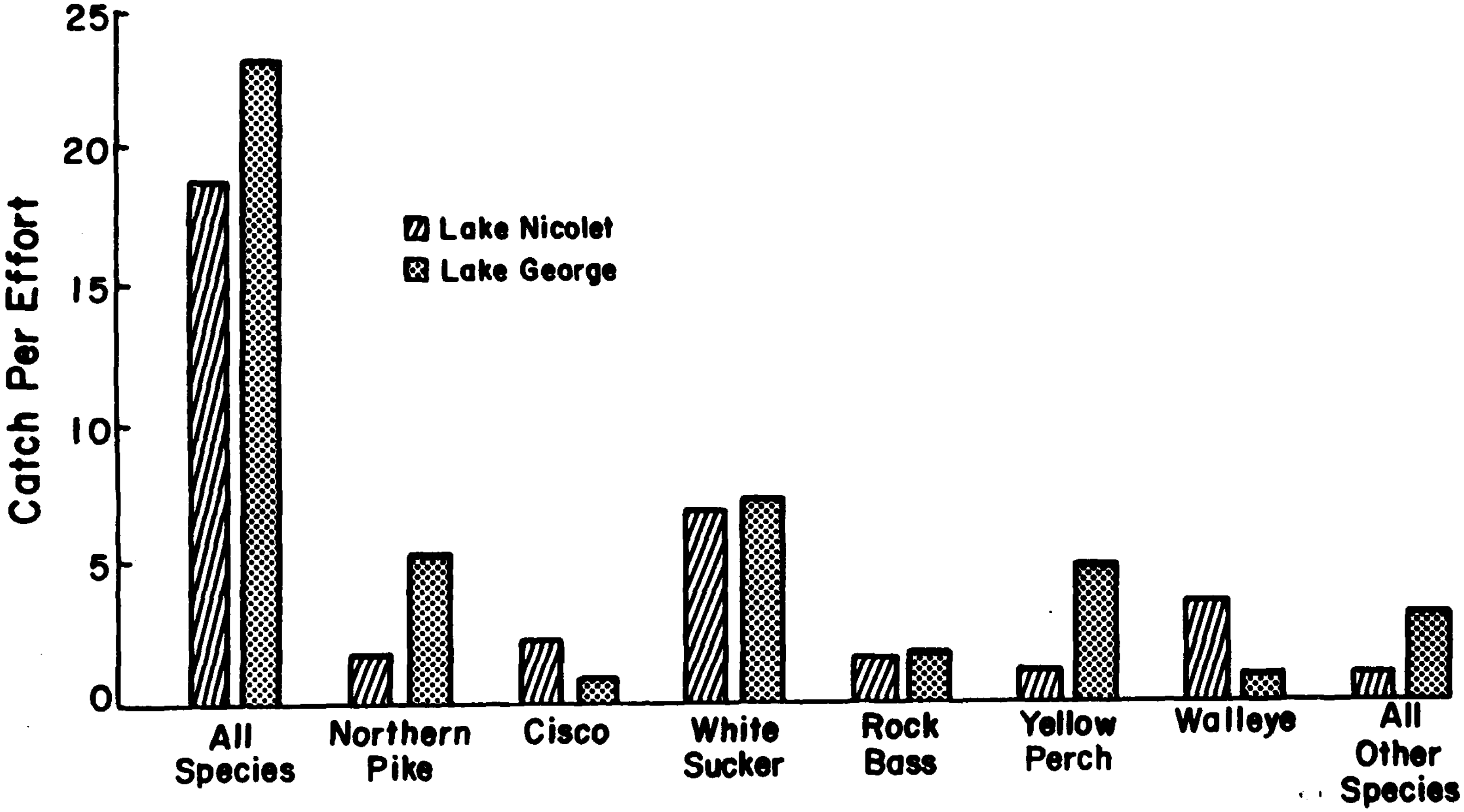


Figure 36. Comparison of catch per effort of major species collected with gill nets during open water months, Navigation Course 5 (Lake Nicolet) vs. Lake George, 1981.

White sucker composed about one third of the catch at both sample sites (Figure 37). Cisco and walleye contributed a greater percentage of the catch in Lake Nicolet than in Lake George (11 and 18.5% vs. 3 and 4%, respectively). In contrast, northern pike and yellow perch composed 21 and 20% of the catch in Lake George as compared to their respective contribution to the Lake Nicolet catch of 8.5 and 9.0%.

Length frequency peaks for white sucker captured in Lake Nicolet and Lake George were dissimilar (Table 25). Although the majority of the catch in both areas was within the interval 376 - 495 mm TL, peaks were noted between 226 - 285 and 316 - 345 mm TL in the Lake Nicolet sample that were not evident in Lake George. Peaks centered at 325, 340, 370, and 385 mm TL were evident in the cisco length frequency distribution from Lake George. Corresponding modes were recorded in Lake Nicolet at 340, 370, and 385 mm with many fish recorded beyond 393 mm TL. A paucity of fish was noted in the Lake Nicolet sample in intervals below 333 mm TL. Comparisons of yellow perch catches between the two sites indicated disparity. Although the modes were similar the proportion of the sample consisting of large fish (269 mm) was slightly greater in Lake Nicolet. In contrast, the Lake George sample contained more fish <180 mm TL. The range and structure of the length frequency distribution for northern pike taken in the two areas was roughly similar with differences primarily a function of sample size (Table 26). Rock bass in the 241 - 250 mm interval occurred with higher frequency in Lake Nicolet. Again, the major portion of the sample fell within a common interval. Greater dispersion, more numerous frequency peaks and greater total numbers were all evident for walleye from Lake Nicolet compared with Lake George. Walleye ranged broadly between 241 - 600 mm TL in the Lake Nicolet sample with frequency peaks recorded at 379, 430, and 470 mm TL.

Small Mesh Trap Nets

Navigation Courses 5, 7 and 9, 1981. A total of 8,103 fish representing 42 species were collected in 82 small mesh trap net samples from the upper littoral zone of Navigation Courses 5, 7 and 9 (Table 27). Bluegill was numerically the most important species, comprising 28.5% of the total catch. Other abundant species in order of decreasing importance included: brown bullhead, yellow perch, bluntnose minnow, white sucker, spottail shiner, sand shiner, mimic shiner, pumpkinseed, common shiner, rock bass and alewife. The majority of the total weight of the catch was accounted for by white suckers (35.5%) and brown bullheads (33.9%).

With all species combined, collections were greater in Navigation Course 9 (catch per effort, CPE = 129.5) than in Navigation Course 7 (CPE = 104.8) or Navigation Course 5 (CPE = 68.7; Figure 38). Collections of the small mesh trap nets in these navigation courses were greater during the day (CPE = 117.6) than at night (CPE = 79.1).

Bluegill was numerically the most important species. Most bluegill were young-of-the-year (98.1%) taken in daylight during summer at Navigation Course 9. About 1.9% were age I. Bluegill were collected in greater numbers during the day (CPE = 48.4) than at night (CPE = 6.9; Figure 39). More bluegill were taken during the summer (June - August, CPE = 56.7) than during the fall

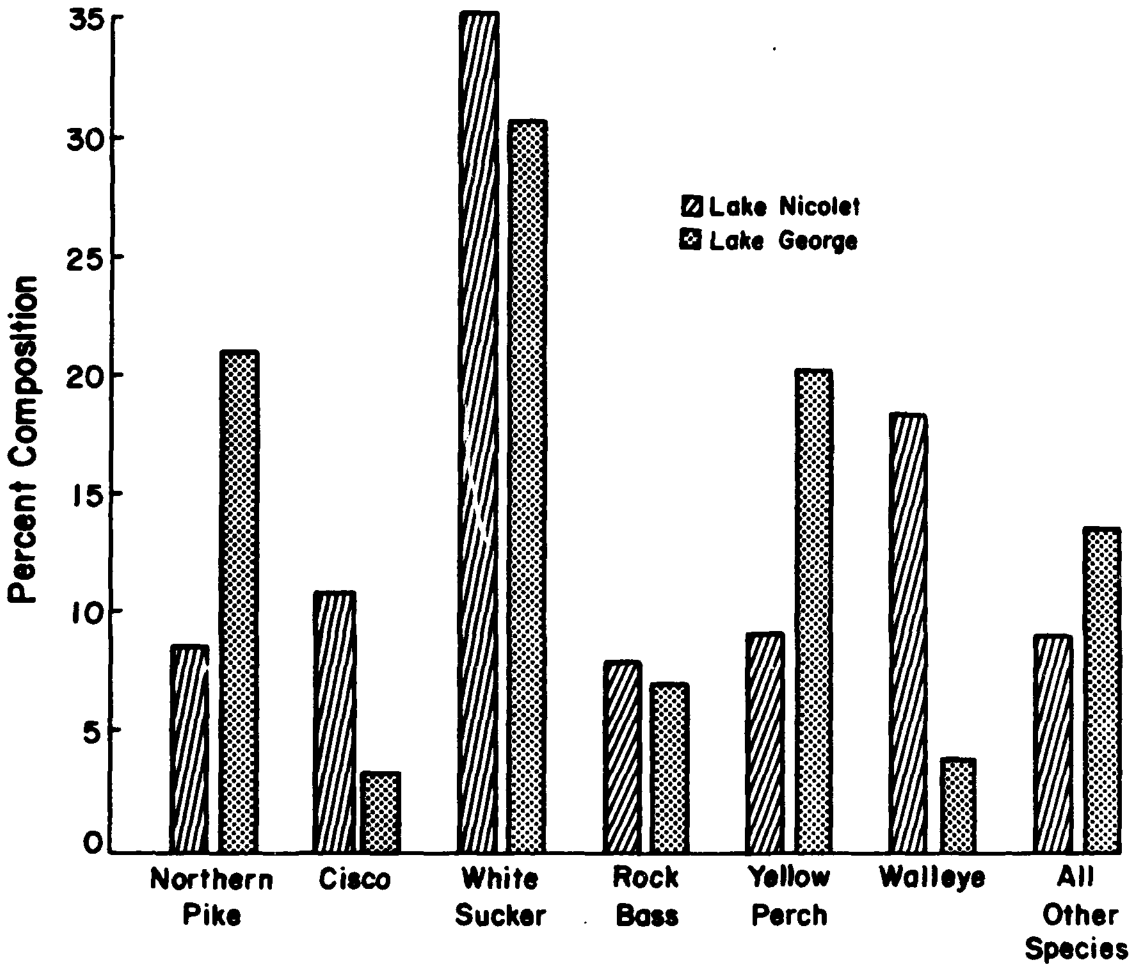


Figure 37. Comparison of percent composition comprised by major species in open water gill net collections taken from Navigation Course 5 (Lake Nicolet) and Lake George, 1981.

Table 27. Summary of all small mesh trap net collections taken during May through November at Navigation Courses 5, 7 and 9 in the St. Marys River, 1981 (N = 82).

Species	Total Number	Percent of Total Number	Catch per Effort	Total Weight (g)	Percent of Total Weight
Bluegill	2,307	28.5	28.1	3,348	2.5
Brown bullhead	1,101	13.6	13.4	45,812	33.9
Yellow perch	1,037	12.8	12.6	3,999	3.0
Bluntnose minnow	913	11.3	11.1	1,953	1.4
White sucker	634	7.8	7.7	47,878	35.5
Spottail shiner	386	4.8	4.7	1,508	1.1
Sand shiner	272	3.4	3.3	526	0.4
Mimic shiner	237	2.9	2.9	403	0.3
Pumpkinseed	208	2.6	2.5	909	0.7
Common shiner	199	2.5	2.4	658	0.5
Rock bass	152	1.9	1.8	4,368	3.2
Alewife	129	1.6	1.6	112	0.1
Emerald shiner	95	1.2	1.2	182	0.1
Ninespine stickleback	92	1.1	1.1	97	0.1
Blacknose shiner	68	0.8	0.8	98	0.1
Smallmouth bass	68	0.8	0.8	2,583	1.9
Golden shiner	46	0.6	0.6	133	0.1
Logperch	27	0.3	0.3	62	<0.1
Central mudminnow	23	0.3	0.3	58	<0.1
Banded killifish	19	0.2	0.2	19	<0.1
Trout-perch	15	0.2	0.2	98	0.1

Continued

Table 27. Concluded

Species	Total Number	Percent of Total Number	Catch Per Effort	Total Weight (g)	Percent of Total Weight
Mottled sculpin	13	0.2	0.2	33	<0.1
Johnny darter	11	0.1	0.1	20	<0.1
Northern pike	9	0.1	0.1	6,803	5.0
Brook stickleback	7	0.1	0.1	10	<0.1
Black crappie	5	0.1	0.1	21	<0.1
Bowfin	4	<0.1	<0.1	7,915	5.9
Slimy sculpin	4	<0.1	<0.1	16	<0.1
Fathead minnow	4	<0.1	<0.1	8	<0.1
Rosyface shiner	3	<0.1	<0.1	22	<0.1
Notropis spp.	3	<0.1	<0.1	3	<0.1
Pearl dace	2	<0.1	<0.1	11	<0.1
Burbot	1	<0.1	<0.1	1,790	1.3
Smelt	1	<0.1	<0.1	3	<0.1
Shorthead redhorse	1	<0.1	<0.1	2	<0.1
Cisco	1	<0.1	<0.1	19	<0.1
Lake whitefish	1	<0.1	<0.1	740	0.6
Largemouth bass	1	<0.1	<0.1	12	<0.1
N. redbelly dace	1	<0.1	<0.1	2	<0.1
Finescale dace	1	<0.1	<0.1	1	<0.1
Walleye	1	<0.1	<0.1	2,760	2.0
Silver lamprey	1	<0.1	<0.1	25	<0.1
TOTAL	8,103	100.0	98.8	135,020	100.0

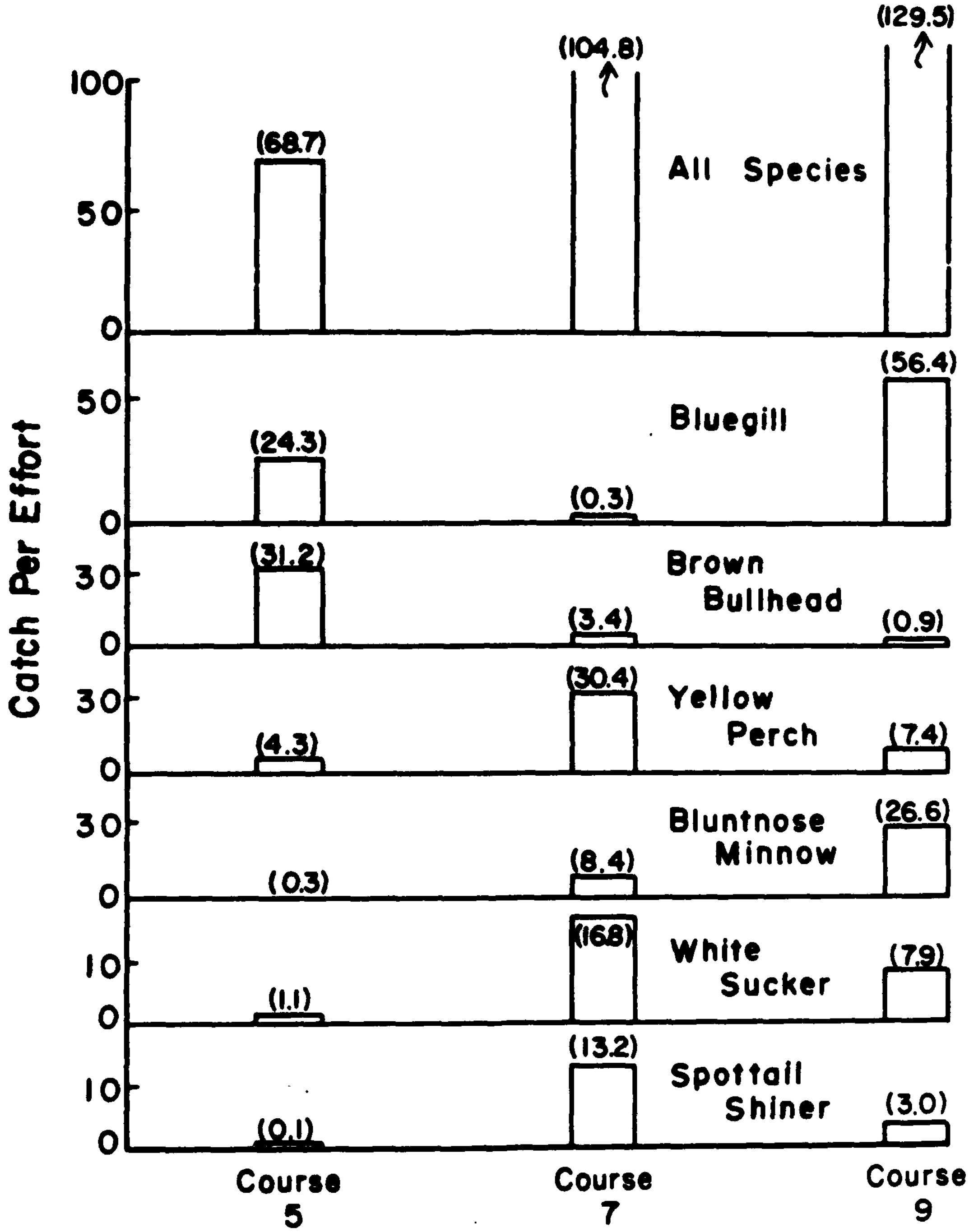


Figure 38. Catch per effort of major species collected with small mesh trap nets at Navigation Courses 5, 7 and 9, St. Marys River, during May through November, 1981 (N = 32, Course 5; N = 23, Course 7; N = 27, Course 9).

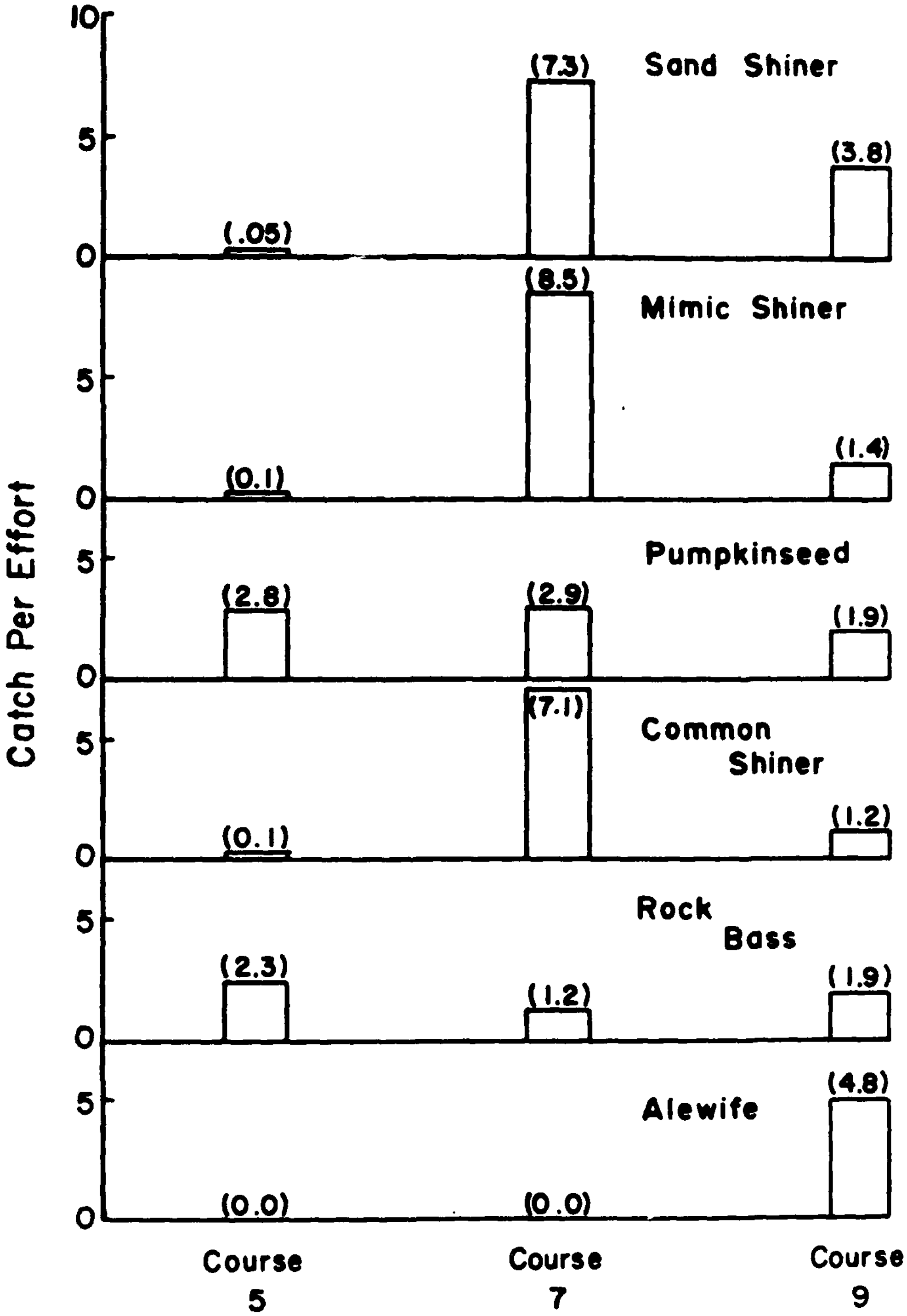


Figure 38. (Continued)

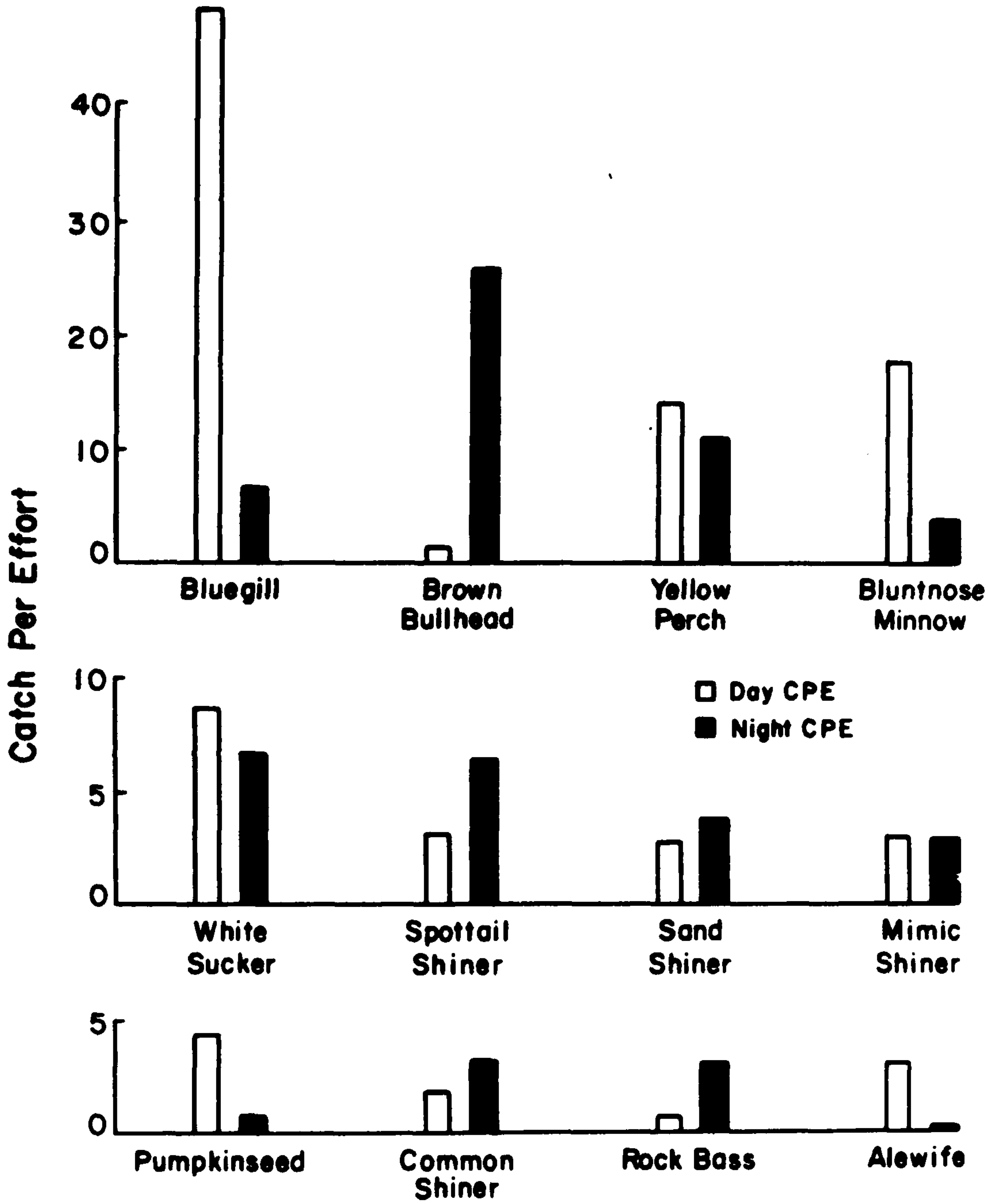


Figure 39. Day and night catch per effort comparisons for major species taken in small mesh trap nets at Navigation Courses 5, 7 and 9, St. Marys River, during May through November, 1981 (N = 42, day; N = 40, night).

(September - November, CPE = 3.1) or spring (May, CPE = 0.0). Bluegill were also more abundant in the littoral zone of Navigation Course 9 than Navigation Course 5 and only a few bluegill were collected in the littoral zone of Navigation Course 7 (Figure 38).

Brown bullheads accounted for 13.6% of the total numbers (CPE = 13.4) and 33.9% of the total weight of the small mesh trap net collections (Table 27). Most brown bullheads were taken in Navigation Course 5 (Figure 38). This species was much more active in the upper littoral zone at night (CPE = 25.9) than during the day (CPE = 1.6) (Figure 39). Fall collections were largest (CPE = 26.3) followed by spring (CPE = 11.1), and finally by summer collections (CPE = 3.9). Unlike most of the other species collected in the upper littoral zone, brown bullheads exhibited a wide range of lengths. Of the individuals processed, 36.4% were less than 100 mm in length, 26.4% were between 100 and 200 mm in length and 37.2% were longer than 200 mm. Individuals in all size ranges were collected in all seasons.

Yellow perch accounted for 12.8% of the small mesh trap net collections (CPE = 12.6). Yellow perch are an important sport fish in the St. Marys River and are abundant throughout the St. Marys system. More yellow perch were taken in Navigation Course 7 than in either Navigation Course 9 or 5 (Figure 38). Relatively large numbers of yellow perch were collected both during the day (CPE = 14.1) and at night (CPE = 11.2; Figure 39). Of the yellow perch aged, 38.1% were young-of-the-year, 57.7% were one year olds and only 2.6% were two year olds. A few fish age III and older were also taken (1.6%). Young-of-the-year yellow perch were first collected during August and were later taken throughout the fall. Most (79.9%) of the age I yellow perch were taken in May, June and July. Catches of age I fish declined in late summer and fall as they apparently moved out of the upper littoral zones. Considering all individuals, more yellow perch were collected during the summer (CPE = 21.1) than during the fall (CPE = 6.6) or spring (CPE = 1.1).

Bluntnose minnows accounted for 11.3% of the total catch (CPE = 11.1). More bluntnose minnows were taken in Navigation Course 9 than in either Navigation Course 7 or 5 (Figure 38). They were also collected in greater numbers during the day (CPE = 17.9) than at night (CPE = 4.1; Figure 39). This species was more abundant in the upper littoral zone during the summer (CPE = 18.0) than during the spring (CPE = 4.3) or fall (CPE = 5.1). Of the individuals measured, 3.4% were smaller than 50 mm in length, 90.3% were between 51 and 75 mm and 6.3% were between 76 and 100 mm in length.

White suckers accounted for 7.8% by number of the small mesh trap net collections (CPE = 7.7) and comprised 35.5% of the total weight. Catches of white suckers were greatest in Navigation Course 7 but they were also moderately abundant in Navigation Course 9 (Figure 38). White suckers were taken both during the day (CPE = 8.7) and at night (CPE = 6.7; Figure 39). Greater numbers of white suckers were collected during the summer (CPE = 9.3) and fall (CPE = 8.2) than during the spring (CPE = 1.5). The larger summer and fall collections included young-of-the-year white suckers. Most white suckers in the upper littoral zone were either young-of-the-year or age I, but older suckers were frequently taken. Of all the individuals measured, 79.6% were less than 200 mm in length while 20.4% were longer than 300 mm.

Spottail shiners were a common forage minnow taken in the trap nets. This species accounted for 4.8% of the catch (CPE = 4.7). Spottail shiners were more abundant in Navigation Course 7 than in Navigation Courses 5 and 9 (Figure 38). Collections at night (CPE = 6.4) were larger than those during the day (CPE = 3.1; Figure 39). More spottail shiners were collected during the summer (CPE = 8.7) than during the spring (CPE = 3.3) or fall (CPE = 0.3). Of the individuals processed, 2.5% were less than 50 mm in length, 59.7% were between 51 and 75 mm, 34.5% were between 76 and 100 mm, and 3.4% were longer than 101 mm. Ages 0 - III were represented in the collections.

Sand shiners and mimic shiners are closely related minnows. Sand shiners accounted for 3.4% of the total catch numerically (CPE = 3.3), while mimic shiners comprised 2.9% of the total catch (CPE = 2.9). The combined weight of these two minnows accounted for less than 1% of the total weight of the catch. Both of these species were collected in greater numbers in Navigation Course 7 than in Navigation Courses 9 or 5 (Figure 38). More sand shiners were taken at night (CPE = 3.8) than during the day (CPE = 2.9), while equal numbers of mimic shiners were collected during both periods (CPE = 2.9; Figure 39). Summer collections of sand shiners (CPE = 6.4) and mimic shiners (CPE = 5.2) were greater than spring (sand shiner CPE = 1.0, mimic shiner CPE = 1.1) or fall collections (sand shiner CPE = 0.3, mimic shiner CPE = 0.7).

Pumpkinseeds accounted for 2.6% of the total catch (CPE = 2.5). Pumpkinseeds were widely distributed in the St. Marys River, but largest numbers were taken in Navigation Courses 5 and 7 (Figure 38). Greater numbers of pumpkinseeds were taken during the day (CPE = 4.3) than at night (CPE = 0.7; Figure 39). Pumpkinseeds were also more abundant in the littoral area during the fall (CPE = 6.3) than summer (CPE = 0.3) or spring (CPE = 0.2). Most pumpkinseeds were young-of-the-year (90.5%) or age I (6.9%), but a few older individuals were taken (2.6%).

Common shiners accounted for 2.5% of the total catch (CPE = 2.4) in the small mesh trap nets. Greatest numbers were taken in the fall (CPE = 4.1) and most were collected in Navigation Course 7 (Figure 38). Spring (CPE = 0.4) and summer (CPE = 1.7) collections of common shiners were much smaller. More common shiners were collected at night (CPE = 3.1) than during the day (CPE = 1.8; Figure 39). Most common shiners in the upper littoral areas were between 51 and 75 mm (76.5%) or 76 and 100 mm (21.6%) in length. A few common shiners were smaller than 50 mm (1.0%) and a few were larger than 100 mm (1.0%).

Rock bass accounted for 1.9% of the total small mesh trap net catch (CPE = 1.8). Rock bass were taken in all areas but more were taken in Navigation Course 5 than in other navigation courses (Figure 38). Unlike the other centrarchids, more rock bass were collected at night (CPE = 3.1) than during the day (CPE = 0.7). More rock bass were also collected during the summer (CPE = 1.8) and fall (CPE = 2.4) than during the spring (CPE = 0.7). The greater summer and fall collections reflect the importance of age 0 rock bass to the overall catch. Ages of rock bass were as follows: age 0 - 73.2%; age I - 8.5%; age II - 1.2%; age III - 3.7%; age IV - 2.4%; age V - 1.2%; age VI - 3.7%; age VII - 4.9%; and age VIII - 1.2%.

Alewife accounted for 1.6% of the total small mesh trap net catch (CPE = 1.6). Alewife were all young-of-the-year taken in the fall (CPE = 4.2) at Navigation Course 9 (CPE = 4.8; Figure 38). All but one alewife were taken during the day (CPE = 3.1; Figure 39). Young-of-the-year alewife apparently use the upper littoral area in Navigation Course 9 as a nursery area.

Other important sport fish taken occasionally in the small mesh trap nets included smallmouth bass, black crappie and northern pike (Table 27). Most smallmouth bass (70.5%) and black crappie (66.7%) were young-of-the-year. Of the northern pike taken, 14.2% were young-of-the-year but most (85.8%) were older.

Lake George, 1981. A total of 11,769 fish representing 35 species were collected in 36 small mesh trap net samples taken in Lake George (Table 28). Spottail shiner, a common forage minnow, was numerically the most important species comprising 51.5% of the total catch. Other abundant species in order of decreasing importance included: common shiner, yellow perch, bluntnose minnow, black crappie, golden shiner, mimic shiner, brown bullhead, white sucker, rock bass, pumpkinseed, bluegill, and smallmouth bass. The majority of the total weight of the catch was accounted for by brown bullhead, northern pike, bowfin, and white sucker (Table 28). When all species were combined collections were much larger during the day (CPE = 575.6) than at night (CPE = 78.2).

Spottail shiners (CPE = 168.3) were numerically the most important species. Most individuals were collected during the day (CPE = 321.9; Figure 40). Spottail shiner abundance was low in the spring (CPE = 0.8), peaked in the summer (CPE = 302.8) and declined sharply during the fall (CPE = 0.1). Most spottail shiners (91.5%) collected were smaller than 76 mm in total length and only 0.8% were larger than 101 mm.

Common shiners accounted for 25.0% of the Lake George collections numerically (CPE = 81.6). Common shiners were collected in greater numbers during the day (CPE = 144.5) than at night (CPE = 18.7; Figure 40). Abundance of common shiners was low in the spring (CPE = 2.3), high in the summer (CPE = 143.0), and low in the fall (CPE = 5.8). Most (77.7%) of the common shiners were less than 51 mm in length, 18.4% were between 76 and 100 mm in length and 3.9% were larger than 101 mm.

Yellow perch (CPE = 21.6) numerically accounted for 6.6% of the Lake George small mesh trap net collections. More yellow perch were taken during the day (CPE = 38.4) than at night (CPE = 4.7; Figure 40). Summer collections (35.9) were greater than spring (CPE = 0.3) or fall collections (CPE = 4.8). Most yellow perch were either young-of-the-year (29.9%) or age I (64.0%). Yellow perch older than age I accounted for 6.1% of the fish aged.

Bluntnose minnows comprised 3.3% of the Lake George small mesh trap net collections (CPE = 10.8). More bluntnose minnows were collected during the day (CPE = 17.9) than at night (CPE = 3.7; Figure 40). Bluntnose minnows were abundant during the summer (CPE = 19.1), and only a few were taken during the fall (CPE = 0.7) and none were taken during the spring. Of the bluntnose minnows processed, 98.6% were less than 76 mm in length.

Table 28. Summary of all small mesh trap net collections taken during May through November in Lake George, St. Marys River, 1981 (N = 36).

Species	Total Number	Percent of Total Number	Catch Per Effort	Total Weight (g)	Percent of Total Weight
Spottail shiner	6,059	51.5	168.3	7,926	5.8
Common shiner	2,938	25.0	81.6	11,551	8.4
Yellow perch	776	6.6	21.6	3,160	2.3
Bluntnose minnow	389	3.3	10.8	760	0.6
Black crappie	267	2.3	7.4	343	0.2
Golden shiner	254	2.2	7.1	642	0.5
Mimic shiner	202	1.7	5.6	290	0.2
Brown bullhead	178	1.5	4.9	24,984	18.2
White sucker	144	1.2	4.0	20,183	14.7
Rock bass	92	0.8	2.6	737	0.5
Pumpkinseed	86	0.7	2.4	2,125	1.5
Bluegill	55	0.5	1.5	61	<0.1
Smallmouth bass	54	0.5	1.5	2,859	2.1
Sand shiner	45	0.4	1.2	71	<0.1
Central mudminnow	36	0.3	1.0	127	0.1
Northern pike	29	0.2	0.8	22,657	16.5
Rosyface shiner	20	0.2	0.6	20	<0.1
Largemouth bass	18	0.2	0.5	77	0.1
Trout-perch	15	0.1	0.4	100	0.1
Logperch	15	0.1	0.4	30	<0.1

Continued

Table 28. (Concluded)

Species	Total Number	Percent of Total Number	Catch Per Effort	Total Weight (g)	Percent of Total Weight
Ninespine stickleback	13	0.1	0.4	13	<0.1
Silver redhorse	13	0.1	0.4	6,980	5.1
Bowfin	13	0.1	0.4	22,431	16.3
Shorthead redhorse	13	0.1	0.4	664	0.5
Gizzard shad	9	0.1	0.2	11	<0.1
Alewife	8	0.1	0.2	12	<0.1
Brassy minnow	7	0.1	0.2	34	<0.1
Emerald shiner	6	<0.1	0.2	15	<0.1
Mottled sculpin	5	<0.1	0.1	26	<0.1
Blacknose shiner	4	<0.1	0.1	7	<0.1
Carp	2	<0.1	0.1	8,730	6.3
Brook stickleback	1	<0.1	<0.1	1	<0.1
Lake chubb	1	<0.1	<0.1	1	<0.1
N. redbelly dace	1	<0.1	<0.1	2	<0.1
Fathead minnow	1	<0.1	<0.1	2	<0.1
TOTAL	11,769	100.0	326.9	137,632	100.0

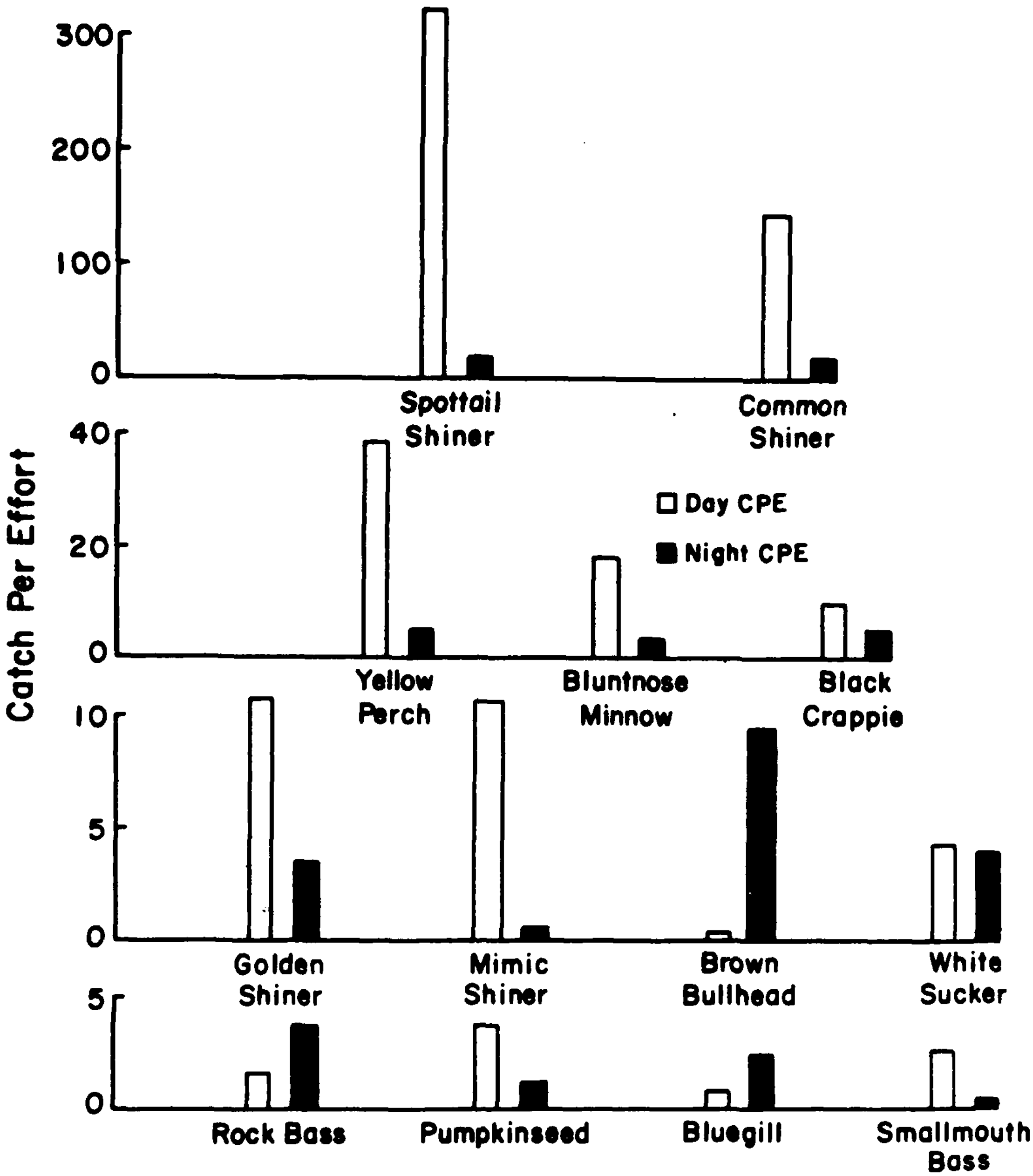


Figure 40. Day and night catch per effort comparisons for major species taken in small mesh trap nets at Lake George during May through October, 1981 (N = 18, day; N = 18, night).

Young-of-the-year black crappie accounted for 2.3% of the total catch (CPE = 7.4). Black crappie numbers in the upper littoral zone peaked in the summer (CPE = 13.1). In the fall, young-of-the-year black crappie apparently moved out of the shallow water (CPE = 0.4). More black crappie were collected during the day (CPE = 9.8) than at night (CPE = 5.1; Figure 40).

Golden shiners comprised 2.2% of the Lake George trap net collections (CPE = 7.1). More golden shiners were taken during the day (CPE = 10.8) than at night (CPE = 3.3; Figure 40). Golden shiner collections were also greater during the summer (CPE = 12.6) than spring (CPE = 0.3) or fall (CPE = 0.1). Size ranges of golden shiners included the following: 26 to 50 mm - 24.7%; 51 to 75 mm - 69.1%; and 76 to 100 mm - 6.2%.

Mimic shiners numerically accounted for 1.7% of the small mesh trap net collections (CPE = 5.6). Mimic shiners were more active in the upper littoral areas during the day (CPE = 10.6) than at night (CPE = 0.6; Figure 40). Although most mimic shiners were taken during the summer (CPE = 10.0) a few were collected in the fall (CPE = 0.2).

Brown bullhead numerically comprised 1.5% of the Lake George small mesh trap net collections (CPE = 4.9). This species also accounted for 18.2% of the total weight of the catch (Table 28). Unlike the cyprinids, more brown bullheads were collected at night (CPE = 9.4) than during the day (CPE = 0.4; Figure 40). Greatest numbers of brown bullhead were taken during the spring (CPE = 5.5). Catches decreased in the summer (CPE = 4.8) and then increased again in the fall (CPE = 5.1). Although most brown bullhead were small, other size classes were present. Size ranges included: 0 to 100 mm - 44.2%; 101 to 200 mm - 16.7%; 201 to 300 mm - 32.5%; and 301 to 400 mm - 6.7%.

White suckers numerically accounted for 1.2% of the total Lake George collections (CPE = 4.0). This species also comprised 14.7% of the total weight of the catch. White suckers were active in the upper littoral zone both at night (CPE = 3.8) and during the day (CPE = 4.2; Figure 40). Catches were small in the spring (CPE = 1.3) but increased during the summer (CPE = 4.3) and fall (CPE = 4.4) due to large collections of young-of-the-year. Individuals less than 200 mm in length accounted for 80.2% of the total catch. Large individuals (>400 mm) were also frequently taken and accounted for 18.7% of the fish collected.

Rock bass comprised 0.8% of the total Lake George trap net collections (CPE = 2.6). Rock bass were taken in greater numbers at night (CPE = 3.6) compared to day (CPE = 1.5; Figure 40). Catches of rock bass were small during the spring (CPE = 0.3) but increased in the summer (CPE = 2.2) and fall (CPE = 3.9) due to collection of young-of-the-year. Of the rock bass aged, 91.9% were age 0, 3.5% were age I, 2.3% were age II, 1.2% were age IV, and 1.2% were age VI.

Pumpkinseeds accounted for 0.7% of the total Lake George trap net collections (CPE = 2.4). More pumpkinseeds were collected during the day (CPE = 3.7) than at night (CPE = 1.1; Figure 40). Although a few pumpkinseed were collected in the summer (CPE = 0.7), most were taken in the fall (CPE = 6.1). Most young-

of-the-year pumpkinseed were collected in the fall and overall they accounted for 86.4% of the individuals sampled. Larger fish up to age VI accounted for the rest of the catch.

Young-of-the-year bluegill accounted for 0.5% of the total Lake George small mesh trap net collections (CPE = 1.5). These fish were collected in the littoral zone during the summer (CPE = 2.2) and fall (CPE = 1.0). More bluegill were taken at night (CPE = 2.4) than during the day (CPE = 0.7; Figure 40).

Young-of-the-year (92.7%) and adult (7.2%) smallmouth bass accounted for 0.5% of the total catch (CPE = 1.5). Smallmouth bass were taken only during the summer (CPE = 2.7) and most were collected during the day (CPE = 2.6; Figure 40).

Other important sport fish collected occasionally in the Lake George trap nets included northern pike (CPE = 0.8) and largemouth bass (CPE = 0.5). All of the largemouth bass were young-of-the-year. Although 18.5% of the northern pike were young-of-the-year, most (81.5%) were age III or older. The large northern pike were apparently feeding on the forage fishes in the upper littoral zone.

Navigation Course 5 vs. Lake George, 1981. A comparison of fish populations in an upper littoral zone adjacent to commercial navigation (Navigation Course 5) and an upper littoral zone removed from the effects of commercial navigation (Lake George) is given in Table 29. Collections of the small mesh trap nets documented larger numbers and greater species diversity in the littoral zone not directly exposed to the effects of commercial navigation. This trend was most apparent for forage species. Small mesh trap net collections from Lake George (CPE = 326.9) were considerably greater than collections from Navigation Course 5 (CPE = 68.7). Thirty-five species of fish were taken in Lake George while twenty-one species were collected in Navigation Course 5. Of 19 species present from both sites, 13 were more abundant in Lake George, three were more abundant in Course 5, and three were equally abundant. Of the important sport fish, yellow perch, smallmouth bass, largemouth bass, white sucker, and northern pike were all taken in greater numbers in Lake George than Navigation Course 5. However, brown bullhead and bluegill were taken in much higher numbers in the navigation course. A few walleye were taken in Navigation Course 5 while none were collected in Lake George (Table 29).

1980 vs. 1981 Comparisons. The total number of fish sampled on comparable dates during 1981 in Navigation Course 5 was 29% greater than in 1980 (Table 30). Total catch was also larger during 1981 in Navigation Courses 7 (20%) and 9 (169%) (Tables 31 and 32).

Variability in catches of individual species during the two years was considerable. In Navigation Course 5 during October 1980 the most abundant species in decreasing order of importance were brown bullhead, white sucker, yellow perch, bluegill and spottail shiner. In 1981 the most important species were brown bullhead, pumpkinseed, central mudminnow, white sucker, and golden shiner (Table 30). Seven of the thirteen species taken during October 1980 were not collected during October 1981.

Table 29. Comparison of 1981 catches from small mesh trap nets set in Navigation Course 5 and Lake George (N = 32, Course 5; N = 36, Lake George).

Species	Navigation Course 5			Lake George		
	Total Number	Percent of Total Number	Catch Per Effort	Total Number	Percent of Total Number	Catch Per Effort
Brown bullhead	999	45.5	31.2	178	1.5	4.9
Bluegill	777	35.4	24.3	55	0.5	1.5
Yellow perch	137	6.2	4.3	776	6.6	21.6
Pumpkinseed	91	4.1	2.8	86	0.7	2.4
Rock bass	73	3.3	2.3	92	0.8	2.6
White sucker	34	1.6	1.1	144	1.2	4.0
Golden shiner	28	1.3	0.9	254	2.2	7.1
Central mudminnow	23	1.1	0.7	36	0.3	1.0
Smallmouth bass	7	0.3	0.2	54	0.5	1.5
Emerald shiner	6	0.3	0.2	6	<0.1	0.2
Northern pike	5	0.2	0.2	29	0.2	0.8
Spottail shiner	3	0.1	0.1	6,059	51.5	168.3
Mimic shiner	3	0.1	0.1	202	1.7	5.6
Bowfin	3	0.1	0.1	13	0.1	0.4
Common shiner	2	0.1	0.1	2,938	25.0	81.6
Sand shiner	1	<0.1	<0.1	45	0.4	1.2
Bluntnose minnow	3	<0.1	<0.1	389	3.3	10.8
N. redbelly dace	1	<0.1	<0.1	1	<0.1	<0.1
Brook stickleback	1	<0.1	<0.1	1	<0.1	<0.1
Silver lamprey	1	<0.1	<0.1	0	0.0	0.0
Walleye	1	<0.1	<0.1	0	0.0	0.0

Continued

Table 29. Concluded

Species	Navigation Course 5			Lake George		
	Total Number	Percent of Total Number	Catch Per Effort	Total Number	Percent of Total Number	Catch Per Effort
Black crappie	0	0.0	0.0	267	2.3	7.4
Rosyface shiner	0	0.0	0.0	20	0.2	0.6
Largemouth bass	0	0.0	0.0	18	0.2	0.5
Trout-perch	0	0.0	0.0	15	0.1	0.4
Logperch	0	0.0	0.0	15	0.1	0.4
Ninespine stickleback	1	<0.1	<0.1	13	0.1	0.4
Silver redhorse	0	0.0	0.0	13	0.1	0.4
Shorthead redhorse	0	0.0	0.0	13	0.1	0.4
Gizzard shad	0	0.0	0.0	9	0.1	0.2
Alewife	0	0.0	0.0	8	0.1	0.2
Brassy minnow	0	0.0	0.0	7	0.1	0.2
Mottled sculpin	0	0.0	0.0	5	<0.1	0.1
Blacknose shiner	0	0.0	0.0	4	<0.1	0.1
Carp	0	0.0	0.0	2	<0.1	0.1
Lake chub	0	0.0	0.0	1	<0.1	<0.1
Fathead minnow	0	0.0	0.0	1	<0.1	<0.1
All Species	2,200		68.7	11,769		326.9

Table 30. Comparison of 1980 and 1981 catches from small mesh trap nets set in Navigation Course 5 during October (N = 6, 1980; N = 8, 1981).

Species	1980 Total Number	1980 Percent of Total Number	1980 Catch Per Effort	1981 Total Number	1981 Percent of Total Number	1981 Catch Per Effort
Brown bullhead	254	55.1	42.3	682	86.4	85.2
White sucker	64	13.9	10.6	14	1.8	1.8
Yellow perch	63	13.7	10.5	0	0.0	0.0
Bluegill	50	10.8	8.3	6	0.8	0.8
Spottail shiner	8	1.7	1.3	0	0.0	0.0
Rock bass	6	1.3	1.0	1	0.1	0.1
Central mudminnow	5	1.1	0.8	23	2.9	2.9
Common shiner	3	0.7	0.5	0	0.0	0.0
Ninespine stickleback	3	0.7	0.5	0	0.0	0.0
Golden shiner	2	0.4	0.3	11	1.4	1.4
Northern pike	1	0.2	0.2	0	0.0	0.0
Brook stickleback	1	0.2	0.2	0	0.0	0.0
Logperch	1	0.2	0.2	0	0.0	0.0
Pumpkinseed	0	0.0	0.0	51	6.5	6.3
Silver lamprey	0	0.0	0.0	1	0.1	0.1
All Species	461	100.0	76.8	789	100.0	98.6

Table 31. Comparison of 1980 and 1981 catches from small mesh trap nets set in Navigation Course 7 during August, September and October (N = 6, 1980; N = 11, 1981).

Species	1980			1981		
	Total Number	Percent of Total Number	Catch Per Effort	Total Number	Percent of Total Number	Catch Per Effort
Sand shiner	194	28.4	32.3	8	0.5	0.7
Blacknose shiner	131	19.2	21.8	36	2.4	3.3
Yellow perch	84	12.3	14.0	263	17.7	23.9
Bluegill	60	8.8	10.0	6	0.4	0.5
White sucker	51	7.5	8.5	351	23.6	31.9
Spottail shiner	36	5.3	6.0	256	17.2	23.3
Common shiner	24	3.5	4.0	123	8.3	11.2
Rock bass	21	3.1	3.5	18	1.2	1.6
Bluntnose minnow	19	2.8	3.2	131	8.8	11.9
Lake chub	13	1.9	2.2	0	0.0	0.0
Brown bullhead	13	1.9	2.2	79	5.3	7.2
Logperch	8	1.2	1.3	4	0.3	0.4
Emerald shiner	6	0.9	1.0	12	0.8	1.1
Mimic shiner	5	0.7	0.8	80	5.4	7.3
Johnny darter	5	0.7	0.8	6	0.3	0.5
Brook stickleback	4	0.6	0.7	0	0.0	0.0
Mottled sculpin	2	0.3	0.3	4	0.3	0.4
Smallmouth bass	2	0.3	0.3	8	0.5	0.7
Golden shiner	2	0.3	0.3	17	1.1	1.5
Blackchin shiner	2	0.3	0.3	0	0.0	0.0

Continued

Table 31. Concluded

Species	1980			1981		
	Total Number	Percent of Total Number	Catch Per Effort	Total Number	Percent of Total Number	Catch Per Effort
Pumpkinseed	0	0.0	0.0	66	4.4	6.0
Ninespine stickleback	0	0.0	0.0	6	0.3	0.5
Slimy sculpin	0	0.0	0.0	4	0.3	0.4
Fathead minnow	0	0.0	0.0	2	0.1	0.2
Pearl dace	0	0.0	0.0	2	0.1	0.2
Largemouth bass	0	0.0	0.0	1	0.1	0.1
Shorthead redhorse	0	0.0	0.0	1	0.1	0.1
Trout-perch	0	0.0	0.0	1	0.1	0.1
All Species	682	100.0	113.7	1,485	100.1	135.0

Table 32. Comparison of 1980 and 1981 catches from small mesh trap nets set in Navigation Course 9 during September and October (N = 4, 1980; N = 7, 1981).

	1980			1981		
Species	Total Number	Percent of Total Number	Catch Per Effort	Total Number	Percent of Total Number	Catch Per Effort
Bluegill	59	54.6	14.8	1	0.2	0.1
Rock bass	15	13.9	3.8	25	4.8	3.6
White sucker	15	13.9	3.8	30	5.8	4.3
Yellow perch	7	6.5	1.8	62	12.0	8.9
Mottled sculpin	4	3.7	1.0	0	0.0	0.0
Johnny darter	2	1.9	0.5	1	0.2	0.1
Carp	1	0.9	0.3	0	0.0	0.0
Emerald shiner	1	0.9	0.3	76	14.7	10.9
Brown bullhead	1	0.9	0.3	5	1.0	0.7
Banded killifish	1	0.9	0.3	0	0.0	0.0
Brook stickleback	1	0.9	0.3	0	0.0	0.0
Trout-perch	1	0.9	0.3	1	0.2	0.1
Alewife	0	0.0	0.0	128	24.7	18.3
Ninespine stickleback	0	0.0	0.0	65	12.5	9.3
Pumpkinseed	0	0.0	0.0	41	7.9	5.9
Bluntnose minnow	0	0.0	0.0	34	6.6	4.9
Blacknose shiner	0	0.0	0.0	25	4.8	3.6
Spottail shiner	0	0.0	0.0	6	1.2	0.9
Common shiner	0	0.0	0.0	4	0.8	0.6
Smallmouth bass	0	0.0	0.0	4	0.8	0.6

Continued

Table 32. Concluded

Species	1980			1981		
	Total Number	Percent of Total Number	Catch Per Effort	Total Number	Percent of Total Number	Catch Per Effort
Sand shiner	0	0.0	0.0	3	0.6	0.4
Black crappie	0	0.0	0.0	2	0.4	0.3
Notropis sp.	0	0.0	0.0	2	0.4	0.3
Burbot	0	0.0	0.0	1	0.2	0.1
Cisco	0	0.0	0.0	1	0.2	0.1
Golden shiner	0	0.0	0.0	1	0.2	0.1
All Species	108	99.9	27.0	518	100.2	74.0

In Navigation Course 7 variability was also considerable (Table 31). In 1980 the most important species were sand shiner, blacknose shiner, yellow perch, bluegill and white sucker. During 1981 the most important species were white sucker, yellow perch, spottail shiner, bluntnose minnow and common shiner. Nine of the twenty-six species taken in 1981 were not collected during 1980. Two species were also collected in 1980 that were not taken during 1981.

In Navigation Course 9 during 1980 the most abundant species were bluegill, rock bass, white sucker, yellow perch and mottled sculpin. During 1981 the most abundant fish were alewife, emerald shiner, ninespine stickleback, yellow perch, and pumpkinseed. Twenty-two species were taken during 1981 while only 12 species were taken in 1980. Four of the fish species taken during 1980 were not collected on comparable dates in 1981 (Table 32).

Some of the variability within species is due to year class strength, because a significant percentage of most fish species in the upper littoral zone during late summer and fall are young-of-the-year. Bluegill and rock bass appeared to have a larger year class in 1980 than 1981. In all three navigation courses on comparable dates they were collected in greater numbers during 1980 (Tables 30 - 32). Brown bullhead, pumpkinseed, and smallmouth bass were taken in greatest numbers during 1981 indicating a stronger year class than 1980 (Tables 30 - 32).

More than one year class of most cyprinids is found in the upper littoral zone and consequently a strong year class may not result in dramatic variation in collection numbers. Emerald shiner and golden shiner populations did appear to increase in 1981. Catches of other species increased at some locations while decreasing at others.

Trawls

Navigation Courses 5, 7 and 9, 1981. A total of 5,997 fish representing 28 species were collected in 30 trawl samples from Navigation Courses 5, 7 and 9 during 1981. Johnny darters were most abundant overall (Table 33) and occurred in all but 1 trawl sample (97%). Other numerically important species were ninespine stickleback, trout-perch, yellow perch, spottail shiner, mottled sculpin, mimic shiner, logperch, white sucker and smelt. White suckers were most important by weight, followed by rock bass, yellow perch, trout-perch and northern pike.

A comparison of catch per effort (CPE) by station and depth of the 15 most abundant species is presented in Figure 41. Catch per effort of all species combined was nearly equal at Courses 7 and 9 while CPE at Course 5 was approximately half that at other stations. Catch in the deep samples was greater than in the shallow areas in Courses 7 and 9, but the opposite was true in Course 5.

Johnny darters were present in all but one sample from Navigation Courses 5, 7 and 9. Catch was higher in Course 7 than either Courses 5 or 9 (α <.002 and .02, respectively; Mann-Whitney U test). Differences between shallow and deep areas were not statistically significant. Johnny darter abundance increased from summer to fall as young-of-the-year were recruited to the trawls.

Table 33. Summary of all trawl collections taken during May through October at Navigation Courses 5, 7 and 9 in the St. Marys River, 1981 (N = 30).

Species	Total Number	Percent of Total Number	Catch per Effort	Total Weight (g)	Percent of Total Weight
Johnny darter	1,157	19.3	38.6	826	1.5
Ninespine stickleback	735	12.3	24.5	680	1.2
Trout-perch	708	11.8	23.6	4,017	7.2
Yellow perch	552	9.2	18.4	6,590	11.9
Spottail shiner	424	7.1	14.1	1,617	2.9
Mottled sculpin	381	6.4	12.7	933	1.7
Mimic shiner	376	6.3	12.5	300	0.5
Logperch	323	5.4	10.8	920	1.7
White sucker	295	4.9	9.8	21,974	39.7
Smelt	261	4.4	8.7	921	1.7
Brook stickleback	207	3.4	6.9	165	0.3
Rock bass	153	2.6	5.1	8,644	15.6
Slimy sculpin	132	2.2	4.4	391	0.7
Common shiner	77	1.3	2.6	103	0.2
Iowa darter	73	1.2	2.4	48	0.1
Sand shiner	72	1.2	2.4	67	0.1
Bluntnose minnow	32	0.5	1.1	78	0.1
Northern pike	10	0.2	0.3	3,303	6.0
Brown bullhead	10	0.2	0.3	1,348	2.4
Emerald shiner	4	0.1	0.1	14	<0.1
Walleye	4	0.1	0.1	2,084	3.8

Continued

Table 33. (Concluded)

Species	Total Number	Percent of Total Number	Catch per Effort	Total Weight (g)	Percent of Total Weight
Bluegill	3	<0.1	0.1	2	<0.1
Black crappie	2	<0.1	0.1	6	<0.1
Pumpkinseed	2	<0.1	0.1	95	0.2
Blacknose shiner	1	<0.1	<0.1	1	<0.1
Cisco	1	<0.1	<0.1	193	0.4
Smallmouth bass	1	<0.1	<0.1	3	<0.1
Notropis spp.	1	<0.1	<0.1	1	<0.1
TOTAL	5,997	100.0	199.9	55,324	100.0

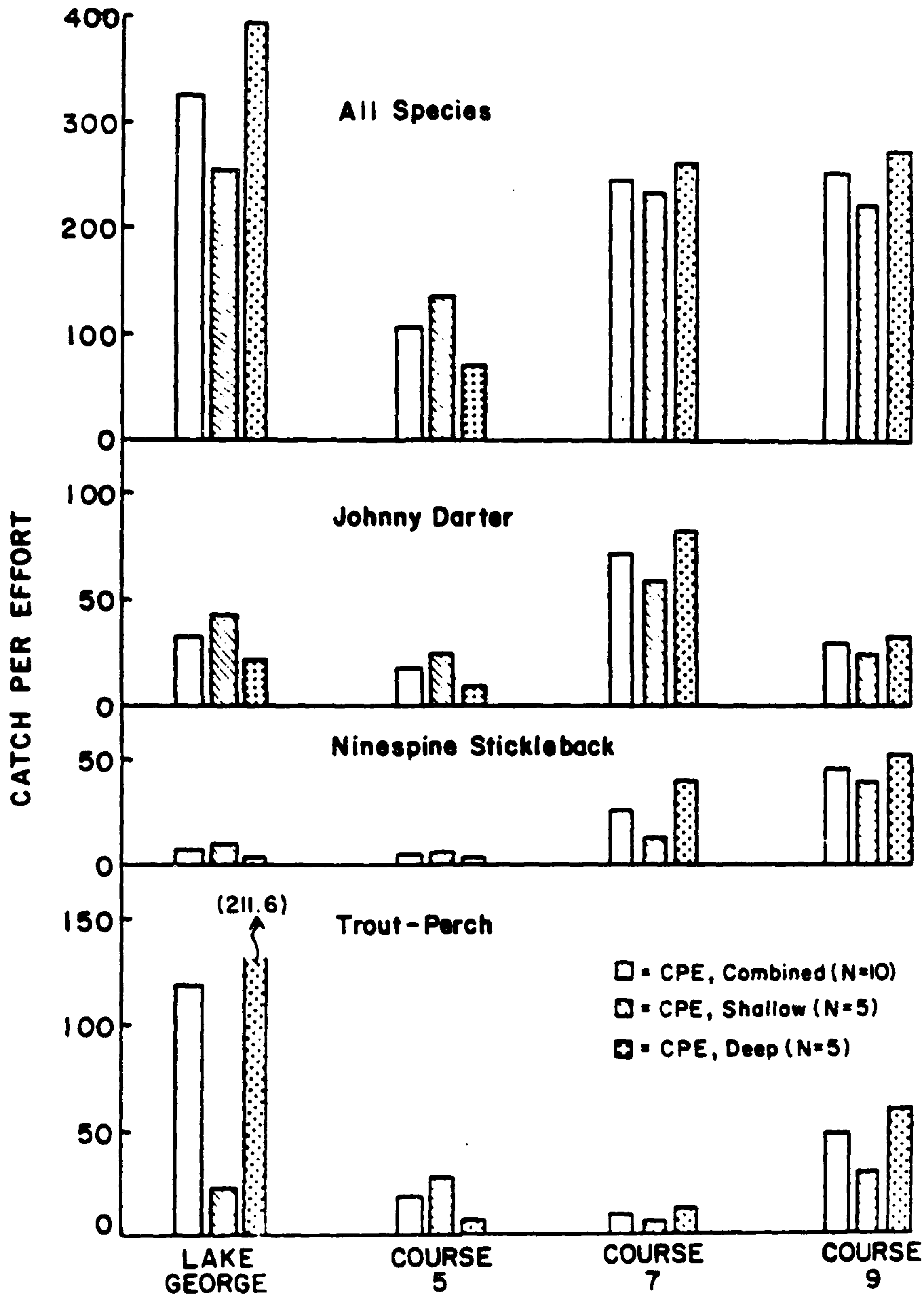


Figure 41. Catch per effort of major species taken with otter trawl in the St. Marys River, 1981.

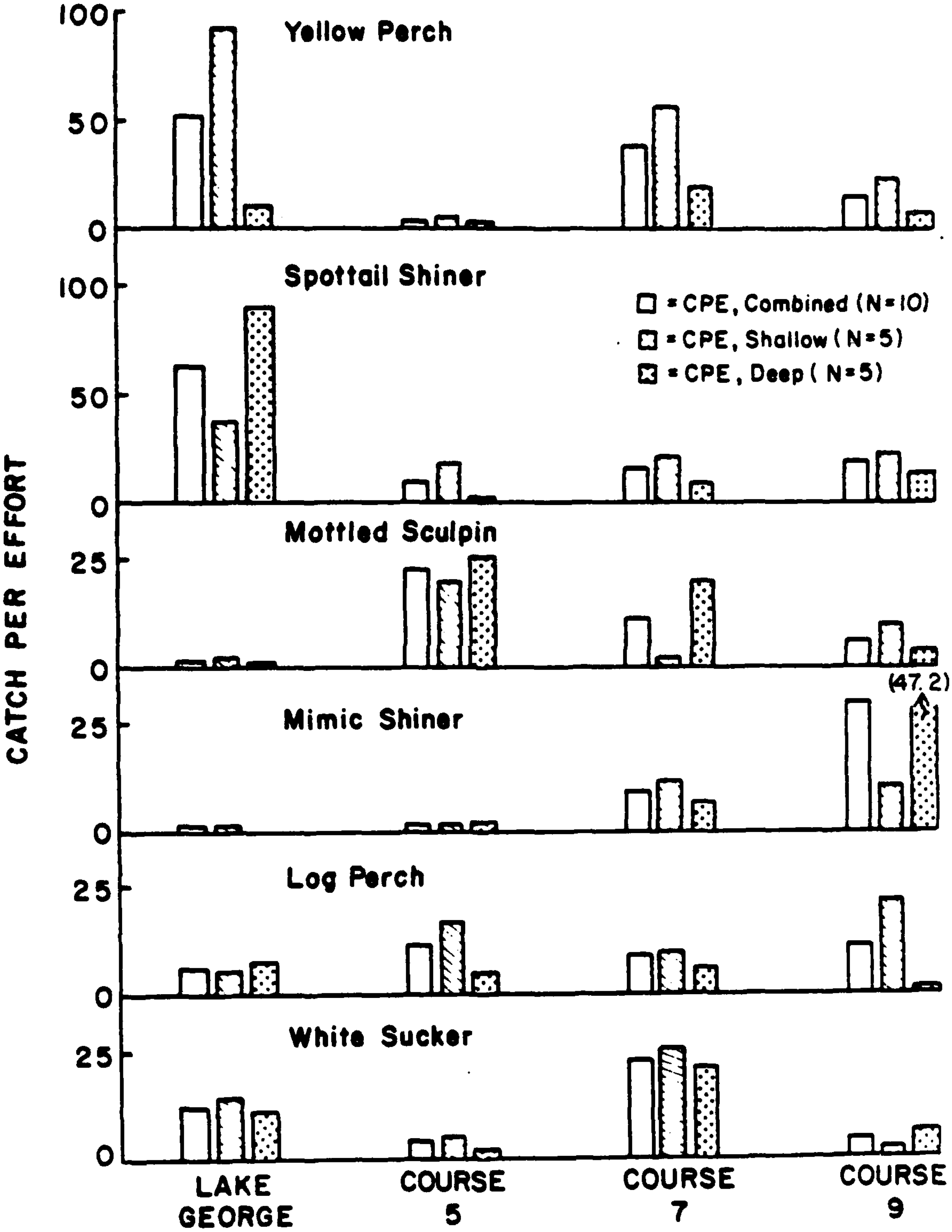


Figure 41. (Cont.)

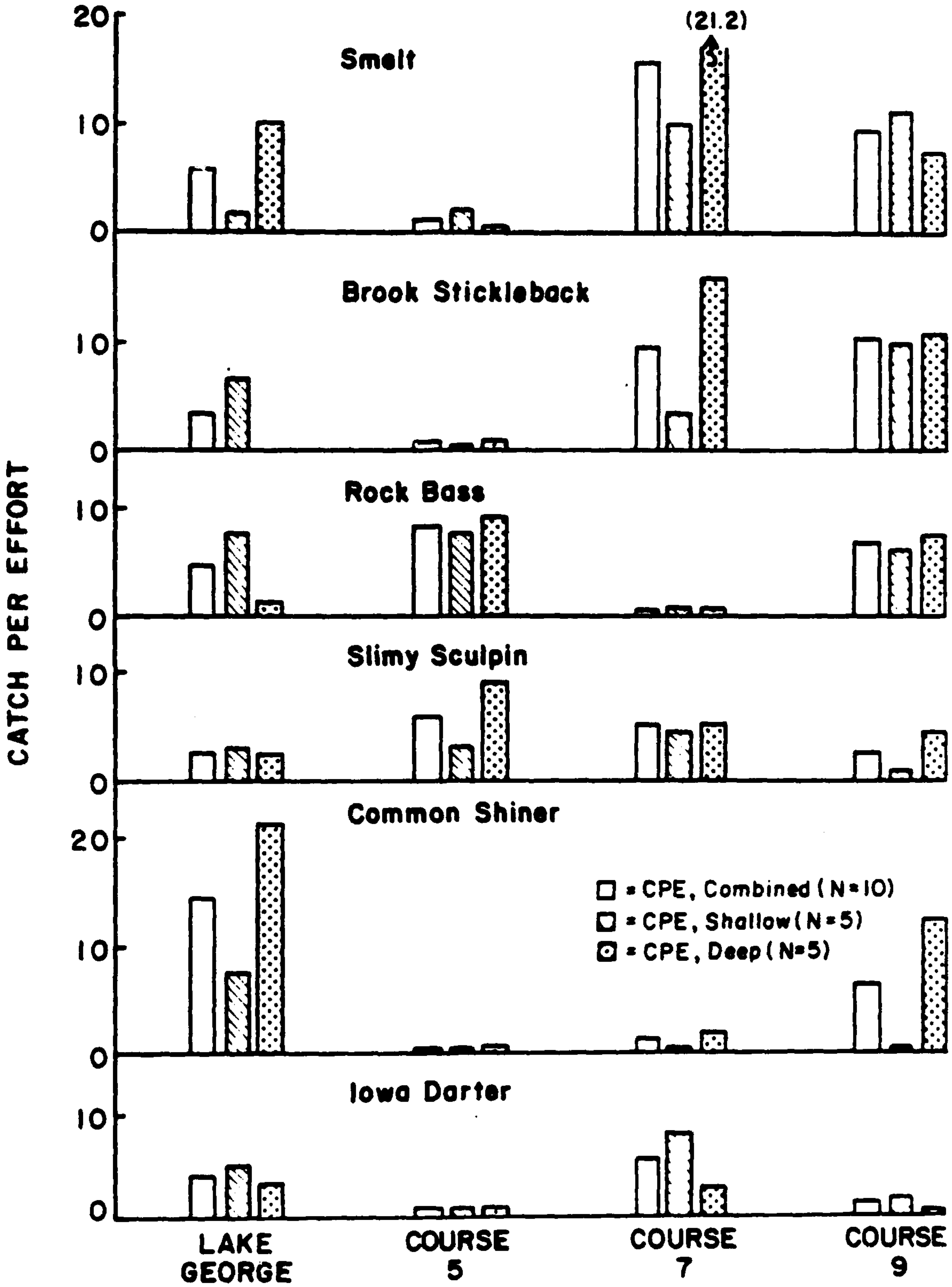


Figure 41. (Cont.)

Ninespine sticklebacks occurred in every trawl sample from Course 7 and in 90% of the samples from both Course 5 and Course 9. Catch per effort was significantly less in Course 5 than in either Courses 7 and 9 (α <.02 for each; Mann-Whitney U Test). Abundance was consistently higher in the deep as compared to the shallow areas of Course 7, but neither Course 5 nor Course 9 displayed such a trend. Catch fluctuated seasonally and no trends were apparent.

Trout-perch were observed in 60% of the Course 5 trawl samples, 80% of the Course 7 samples and 90% of the samples from Course 9. Catch per effort was greater at Course 9 than either Course 5 or Course 7, though the difference was significant only at α <0.10 (Mann-Whitney U Test). Catch was highest in the deep areas of Courses 7 and 9 on all but one sample date. Depth of greatest abundance of trout-perch fluctuated in Course 5, however. Peak abundance of trout-perch in trawls occurred in early summer at each station with a second, smaller peak apparent in Course 9 in September, which probably represented recruitment of young-of-the-year to the trawls.

Yellow perch was the only species of major commercial importance captured consistently in the trawl samples. Perch were present in only 50% of the Course 5 samples but occurred in 90% of the Course 7 and 100% of the Course 9 trawl samples. Comparison of catch between stations also showed that abundance was lower in Course 5 than either Course 7 or Course 9 (α <.05 and α <0.10, respectively; Mann-Whitney U Test). Overall CPE was greater in the shallow as compared with the deep samples at each station, though this varied from date to date. Peak CPE of yellow perch occurred in the summer. The yellow perch captured by trawls from Courses 5, 7 and 9 ranged in total length (TL) from 32 mm to 250 mm. Approximately 12% exceeded 150 mm (6"). Perch taken from Course 5 were generally smaller than those from the other stations and apparently fewer adults were present there. Young-of-the-year began to be recruited to the trawls during late summer and were present in all areas sampled.

Overall, spottail shiners were the most abundant cyprinid, although they were second to the mimic shiner in Course 9. Spottails were present in 60% of the trawls in Course 5 and in 90% of both Course 7 and Course 9 samples. Catch per effort of spottail shiners was similar in Courses 5, 7 and 9. Overall CPE was highest in the shallow samples at all three stations, but data from the individual sample dates did not display this consistently. Peak CPE in Courses 7 and 9 occurred in late summer, while the catch in Course 5 was greatest in late spring and declined thereafter. Both young-of-the-year and adult spottail shiners were represented in the trawl samples. The overall range of total lengths was 23 - 110 mm. Young-of-the-year were not recruited until early fall, while adults were captured consistently through all seasons. However, spottail shiners greater than 50 mm were not captured in Course 7 until late summer, and those captured in Course 7 were smaller than spottails from Courses 5 and 9 through the spring and summer.

Mottled sculpins were present in 50% of the trawl samples in Courses 5 and 9 and occurred in 70% of the Course 7 samples. Abundance was highest in Course 5 and lowest in Course 9 but differences were not statistically significant. Overall CPE was highest in the deep samples from Courses 5 and 7, but CPE from the shallow area was greater than in the deep in Course 9. These

trends were not consistent between sample dates however. Peak catches occurred in late spring in Courses 5 and 7 but not until late summer in Course 9.

Mimic shiners occurred in only 30% of the trawl samples in each of Courses 5, 7 and 9, but they were the most abundant cyprinid in Course 9. Catch per effort of mimic shiners was much greater in Course 9 than either Course 5 or 7, but the difference was not significant since the high value in Course 9 was caused by only one large sample. No consistent differences between shallow and deep catches were apparent. This species was captured relatively infrequently and seasonal trends were difficult to discern.

Logperch were captured frequently in the trawls, occurring in 80% of the samples from Course 5, 90% of those from Course 7 and 70% of the Course 9 samples. Catch per effort of logperch was approximately equal at all three stations and was greatest in the shallow areas at all three sites. Catches fluctuated through the sampling season and no seasonal trends were apparent.

White suckers were the most important species by weight and were captured in some 80% of the samples taken in Courses 5, 7 and 9. The catch was significantly greater in Course 7 than either Course 5 or 9 (α <.05 in both cases; Mann-Whitney U Test). Peak CPE occurred in early summer at each station. White sucker specimens ranged in length from 33 to 483 mm TL, and included young-of-the-year and mature adults. Young-of-the-year were first captured by trawl in late summer and continued to grow into recruitable size through fall. Nearly 20% of the white suckers captured were over 150 mm (6") in total length and 13% were greater than 300 mm (12"). Apparently the trawl sampled all length classes adequately. No consistent differences were noted in abundance distribution by depth.

Smelt were captured with nearly the same frequency in Course 9 (90% of samples) and Course 7 (80%) but were taken in only 40% of the samples in Course 5. Abundance of smelt in Course 5 was significantly less (α <.02; Mann-Whitney U Test) than the abundance at Courses 7 and 9, while no difference between Courses 7 and 9 was demonstrated. Depth distribution varied between stations and no consistent pattern was apparent. Greatest catches occurred in early summer and a second peak occurred in early fall in Course 7 as young-of-the-year became susceptible to the trawl. The overall length range of smelt captured was 24 - 160 mm TL with the average total length being 73 mm. No difference in length distribution between stations could be determined.

Brook stickleback were captured in 80% of the trawls in Course 9, 70% in Course 7 and only 40% of the samples in Course 5. Abundance was significantly lower in Course 5 than in either Courses 7 or 9 (α <.05; Mann-Whitney U Test). Brook stickleback were consistently more abundant in the deep samples from Course 7 as compared to the shallow areas, but no such trends were noted in Courses 5 or 9. Seasonal peak catches varied by station with the highest catch in Course 7 occurring in the spring and the peak abundance in Course 9 occurring in late summer.

Catch per effort for rock bass was higher in Course 5 than in Course 7 (α <.02; Mann-Whitney U Test) but no other significant differences were observed between stations. Rock bass were captured in 60% of the Course 5

trawl samples, 80% of the Course 9 samples, but were present in only 30% of the samples from Course 7. Overall CPE was slightly higher in the deep than in the shallow areas but depth distribution varied by date. Few rock bass were caught in trawls early in the sampling season. Peak abundance occurred in late summer and early fall. Approximately 37% of the rock bass captured were young-of-the-year and 31% were adults over 150 mm (6") TL. Specimens captured in Course 7 during the fall were all young-of-the-year while samples from Courses 5 and 9 contained mixed ages.

Slimy sculpins were captured in only 40% of the trawls at each of Courses 5, 7 and 9. No differences in abundance between courses were statistically significant. Slimy sculpins were consistently caught in greatest numbers in the deep trawl samples and all were captured in the late summer and early fall. Young-of-the-year represented approximately 15% of the catch and the largest adult captured measured 100 mm (4") in total length.

Common shiners were captured infrequently in Courses 5, 7 and 9, occurring in 23% of the trawl samples. Over 80% of the common shiners caught were from Course 9 but no significant differences could be shown due to the infrequent occurrence. Most specimens were in the deep areas and all were taken in late summer and early fall.

Iowa darters were captured regularly throughout the sampling period though only rarely in substantial numbers. They were present in 30% of the Course 5 samples, 60% of the Course 7 samples and 40% of the trawl samples from Course 9. No significant differences between stations were noted, and no consistent trends in depth distribution were observed. Approximately 26% of the late summer and early fall catch of Iowa darters were young-of-the-year fish (20 - 30 mm TL).

Fish of importance to the local sports fishery that were rare in the Course 5, 7 and 9 trawl samples included northern pike, brown bullhead, walleye, cisco, smallmouth bass and three species of panfish (bluegill, black crappie and pumpkinseed) (Table 33). No northern pike were captured in Course 5 or Course 7, but 60% of the Course 9 trawl samples contained this species. The northern pike were captured at Course 9 in small numbers throughout the season. All were mature adults and ranged from 288 to 454 mm TL. Brown bullheads were not captured in Course 7 or 9, but occurred in 30% of the Course 5 samples. All were mature and fell in the narrow length range of 204 - 232 mm TL. The walleye were captured in Courses 7 and 9 during August. All were mature and ranged from 254 to 451 mm TL. One cisco was captured by trawl in a June sample from Course 7. That individual was a mature male 265 mm in total length. One smallmouth bass was captured during August at Course 5. That individual was an immature young-of-the-year fish 55 mm TL. Three bluegills captured in one sample from Course 9 in August were young-of-the-year (30 - 34 mm TL). Two black crappies and two pumpkinseeds were taken from Course 9 in two trawl samples. Both of the black crappies were immature yearlings (62 and 67 mm TL) while one pumpkinseed was a mature female (201 mm TL) and the other an immature yearling (65 mm TL). The fact that these game species were merely incidental to the total catch may be due in part to avoidance of the trawl gear. However, these species tend to prefer shallower, weedy areas that were not sampled by the trawl.

Lake George, 1981. A total of 3,234 fish representing 23 species were collected in 10 trawl samples from Lake George. Trout-perch was most abundant overall (Table 34) occurring in 90% of the samples. Spottail shiner was next in abundance numerically occurring in all Lake George trawl samples. Other numerically important species, in order of abundance (with respective frequency occurrence) were yellow perch (90%), johnny darter (90%), common shiner (40%), white sucker (100%), logperch (70%), smelt (80%), ninespine stickleback (60%), rock bass (50%), Iowa darter (60%), brook stickleback (40%), slimy sculpin (30%), mottled sculpin (50%) and bluntnose minnow (20%). White sucker was most important by weight, followed by trout-perch, yellow perch, northern pike and rock bass.

A comparison of CPE at deep and shallow stations of 15 abundant species is presented in Figure 41. Overall, more specimens were taken in the deep near-channel area compared to the shallow nearshore area of Lake George.

Of the forage fish, trout-perch, spottail shiner, smelt and common shiner were much more abundant at the deep station, although only trout-perch were caught in consistently higher numbers there. Catch per effort of johnny darters and Iowa darters was consistently greatest in the nearshore area. Brook stickleback occurred in shallow samples only. Distributional differences were not apparent for other forage species.

Yellow perch, smelt, white suckers, and rock bass were the only species of direct interest to sport fishing that occurred with regularity. Both the yellow perch and rock bass were more abundant in the shallow, nearshore samples and were captured in greater numbers there consistently. Smelt were more abundant in the deep samples. White suckers did not display any consistent depth preference.

Approximately 8% of the yellow perch were over 150 mm (6") in total length. Mean length by date declined from May to a low of 78 mm in September, paralleling the influx of young-of-the-year perch into the samples. The mean length of yellow perch in the October sample increased to 88 mm reflecting the growth of the 1981 year class. Peak CPE occurred in early fall as the young-of-the-year were recruited into the samples.

The average length of smelt displayed a pattern similar to the yellow perch with a peak in May and a decline to a low in late summer (August). Again, this was due to recruitment of young-of-the-year to the trawl. Although smelt were captured quite regularly, CPE was never high and peaked in late summer at 17 fish per sample.

About 20% of the rock bass captured by trawling in Lake George were over 150 mm (6"). The average total length was 87 mm, with a range of 25 to 262 mm. Most rock bass were captured in the late summer and early fall and over half were young-of-the-year.

Catch per effort of white suckers in Lake George peaked in the spring and again in early fall. Approximately 50% of the spring sample was made up of yearling fish (53 - 94 mm TL) and about 17% were mature adults. The remainder of the spring specimens were a mix of yearlings and 2 year old fish (108 - 200

Table 34. Summary of all trawl collections taken during May through October in Lake George, 1981 (N = 10).

Species	Total Number	Percent of Total Number	Catch per Effort	Total Weight (g)	Percent of Total Weight
Trout-perch	1,172	36.2	117.2	3,940	15.4
Spottail shiner	617	19.1	61.7	816	3.2
Yellow perch	505	15.6	50.5	3,902	15.3
Johnny darter	323	10.0	32.3	237	0.9
Common shiner	141	4.4	14.1	230	0.9
White sucker	124	3.8	12.4	11,212	43.9
Logperch	63	2.0	6.3	119	0.5
Smelt	56	1.7	5.6	108	0.4
Ninespine stickleback	52	1.6	5.2	26	0.1
Rock bass	43	1.3	4.3	1,474	5.8
Iowa darter	39	1.2	3.9	29	0.1
Brook stickleback	34	1.0	3.4	13	<0.1
Slimy sculpin	24	0.7	2.4	46	0.2
Mottled sculpin	12	0.4	1.2	25	0.1
Bluntnose minnow	12	0.4	1.2	22	0.1
Northern pike	6	0.2	0.6	1,912	7.5
Shorthead redhorse	3	0.1	0.3	333	1.3
Pumpkinseed	2	0.1	0.2	3	<0.1
Brown bullhead	2	0.1	0.2	946	3.7
Black crappie	1	<0.1	0.1	2	<0.1
Smallmouth bass	1	<0.1	0.1	64	0.2
Mimic shiner	1	<0.1	0.1	2	<0.1
Walleye	1	<0.1	0.1	72	0.3
TOTAL	3,234	100.0	323.4	25,533	100.0

mm TL). Young-of-the-year made up 97% of the catch of white suckers in the late summer and early fall samples. Over 50% of the white suckers in the October sample were over 300 mm TL (12").

Species of importance to sport and commercial fisheries that were incidental in Lake George trawl samples included northern pike, pumpkinseed, brown bullhead, black crappie, smallmouth bass and walleye (Table 34). Northern pike were the most frequently captured of these and were present in samples from three dates. Total lengths of northern pike averaged 353 mm and ranged from 272 to 503 mm. The pumpkinseeds were captured on one date (October 13) and were young-of-the-year. Both brown bullheads were captured on the same date and were mature adults (251 mm and 355 mm TL). Only one each of black crappie, smallmouth bass and walleye were captured in Lake George trawls. The black crappie and smallmouth bass were young-of-the-year captured in October and August, respectively. The walleye was captured in September and was a mature adult (212 mm TL).

Navigation Course 5 vs. Lake George, 1981. Trawl samples in Course 5 captured fewer species and fewer numbers of fish than those in Lake George (Table 35). A total of 1,028 fish representing 20 species were observed in Course 5 trawls. One species, emerald shiner, was captured in Course 5 that was not observed in Lake George, while five species were collected in Lake George but not in Course 5. Overall CPE in Lake George was more than three times higher than at Course 5. As can be seen in Table 35 and Figure 37, major differences between the two stations occurred in the total number and percent composition of several species. Mottled sculpins were much more important in the Course 5 samples than in Lake George. Rock bass, slimy sculpins, brown bullheads and mimic shiners were each at least twice as abundant in samples from Course 5. Conversely, trout-perch, johnny darters, spottail shiners, white suckers, yellow perch, smelt, Iowa darter, brook stickleback, bluntnose minnows and common shiners were much more abundant in Lake George.

Sampling station differences in average lengths were apparent for several key species. The range of lengths of yellow perch was much wider in Lake George (45 - 260 mm TL) than in Course 5 (32 - 165 mm TL), although this may have been a function of the larger population in the Lake George area. Approximately 95% of the yellow perch in Course 5 were young-of-the-year and yearlings while only about 80% of the Lake George yellow perch were in this group. The few smelt captured by trawl in Course 5 were mature adults (136 - 160 mm TL) while the specimens captured in Lake George ranged from young-of-the-year to adults (27 - 171 mm TL). The white sucker populations in the two areas displayed similar length ranges even though CPE was much higher in Lake George. The length range and average lengths of rock bass captured in Course 5 and Lake George were nearly equal, with a mean of 87 mm and overall range of 21 to 261 mm TL. All of the brown bullheads trawled in both areas were mature adults and no difference in lengths was apparent. Further comparisons of populations of important species from the two areas awaits completion of age analysis.

1980 vs. 1981 Comparisons. Summer catch data from Navigation Courses 7 and 9 were used to compare 1980 and 1981 trawl samples (Table 36). Summer

Table 35. Comparison of the total number and percentage composition of fish species taken with trawls in Navigation Course 5 (n = 10) and Lake George (n = 10) of the St. Mary's River during 1981.

Species	Navigation Course 5 Total Number	Navigation Course 5 Percent of Total Number	Lake George Total Number	Lake George Percent of Total Number
Mottled sculpin	217	21.1	12	0.4
Trout-perch	166	16.2	1172	36.2
Johnny darter	162	15.8	323	10.0
Logperch	104	10.1	63	2.0
Spottail shiner	89	8.7	617	19.1
Rock bass	80	7.8	43	1.3
Slimy sculpin	58	5.6	24	0.7
White sucker	36	3.5	124	3.8
Ninespine stickleback	36	3.5	52	1.6
Yellow perch	29	2.8	505	15.6
Smelt	10	1.0	56	1.7
Brown bullhead	10	1.0	2	0.1
Iowa darter	8	0.8	39	1.2
Brook stickleback	7	0.7	34	1.0
Mimic shiner	5	0.5	1	<0.1
Bluntnose minnow	4	0.4	12	0.4
Emerald shiner	3	0.3	0	0
Common shiner	2	0.2	141	4.4
Smallmouth bass	1	0.1	1	<0.1
Notropis spp	1	0.1	0	0
Northern pike	0	0	6	0.2
Shorthead redhorse	0	0	3	0.1
Pumpkinseed	0	0	2	0.1
Black crappie	0	0	1	<0.1
Walleye	0	0	1	<0.1
Totals	1028	100.0	3234	100.0

Table 36. Comparison of 1980 and 1981 trawl catch data taken during summer from Navigation Courses 7 and 9, St. Mary's River.

Species	1980 (n=8) Total Number	1980 (n=8) Percent of Total Number	1980 (n=8) Catch Per Effort	1981 (n=12) Total Number	1981 (n=12) Percent of Total Number	1981 (n=12) Catch Per Effort
Trout-perch	631	27.4	78	333	10.8	28
Spottail shiner	431	18.7	54	231	7.5	4
Johnny darter	334	14.5	42	543	17.5	45
Mottled sculpin	211	9.2	26	75	2.4	6
Yellow perch	161	7.0	20	416	13.4	35
White sucker	151	6.6	19	184	5.9	15
Mimic shiner	110	4.8	14	52	1.7	4
Brook stickleback	80	3.5	10	133	4.3	11
Ninespine stickleback	60	2.6	8	443	14.3	37
Rainbow smelt	50	2.2	6	197	6.4	16
Logperch	35	1.5	4	200	6.5	17
Sand shiner	9	0.4	1	50	1.6	4
Rock bass	7	0.3	1	42	1.4	4
Walleye	7	0.3	1	4	0.1	0.3
Emerald shiner	6	0.3	1	0	0	0
Blacknose shiner	5	0.2	1	0	0	0
Common shiner	4	0.2	0.5	55	1.8	5
Iowa darter	4	0.2	0.5	52	1.7	4
Northern pike	3	0.1	0.5	6	0.2	0.5
Smallmouth bass	2	0.1	0.2	0	0	0
Brown bullhead	1	<0.1	0.1	0	0	0
Slimy sculpin	0	0	0	69	2.2	6
Bluntnose minnow	0	0	0	5	0.2	0.4
Bluegill	0	0	0	3	0.1	0.2
Black crappie	0	0	0	1	<0.1	0.1
Pumpkinseed	0	0	0	1	<0.1	0.1
Cisco	0	0	0	1	<0.1	0.1
Total	2302	100.0	288	3096	100.0	258

samples were taken in July and August of 1980 and in June and August of 1981. A total of 8 samples were taken in 1980 and 12 were taken in 1981. Data from 1979 trawls were not directly comparable since samples were taken during daylight in that year.

The fish community represented in the trawl samples from Courses 7 and 9 changed substantially in 1981 as compared to 1980 (Table 36). Seven of the ten most abundant species present in 1980 trawls exhibited a change in CPE by a minimum of 75%. Catch per effort of trout-perch, spottail shiner, mottled sculpin, and mimic shiner decreased strongly from 1980 to 1981. None of the declines were significant statistically, however (Mann-Whitney U Test), which can be explained in part by the presence of one or two large outlying samples in the 1980 data. Yellow perch CPE increased by 75% though the change was not statistically significant because of high catch variability. Catch per effort of smelt, ninespine sticklebacks and logperch increased significantly in 1981 ($\alpha < .05$, Mann-Whitney U Test). Catch per effort for all species combined declined by about 10%.

Relative abundances of the major species changed from the 1980 to the 1981 samples (Figure 42). Community comparisons using percent of total numbers caught can sometimes be biased due to the random capture of large numbers of a particular species, but this was apparently not the case with the data under discussion. The total number of fish captured by trawl in each year was not significantly different (Mann-Whitney U Test), therefore the bias is not important. In 1980, trout-perch, spottail shiners and johnny darters each comprised over 10% of the catch by numbers and together made up over 60% of the total number of fish caught. The order of importance in 1981 changed to johnny darters, ninespine stickleback, yellow perch and trout-perch, respectively, and these species comprised 56% of the total number. Spottail shiners, white sucker, smelt, and logperch made up another 26% of the total catch in the summer of 1981. In general, the fish community apparently changed from one dominated by trout-perch in 1980 to a somewhat more balanced community in 1981.

Length data of several fish species taken from Courses 7 and 9 during August of 1980 and 1981 were analyzed and three important species displayed a change in mean length between years. The mean length of yellow perch in 1981 was significantly less than in 1980 ($\alpha < .01$, t-test). Over 62% of the yellow perch taken in August 1980 were less than 60 mm TL (young-of-the-year) while only 4% of those from 1981 were so. Young-of-the-year yellow perch were never abundant in the 1981 trawl samples. Trout-perch mean length was lower in 1980 than in 1981 ($\alpha < .001$) due to a high abundance of young-of-the-year in 1980. Over 65% of the trout-perch taken in August 1980 were 40 mm or less in total length as compared to only 2% in 1981. No other young-of-the-year trout-perch were observed in 1981. More young-of-the-year spottail shiners were captured in 1980 than in 1981. Over 15% of the spottails taken in August 1980 were less than 40 mm, while no young-of-the-year were captured in August 1981. Approximately 10% of the spottail shiners observed in September of 1981 were young-of-the-year (less than 40 mm TL) as compared to nearly 60% in September of 1980. These differences led to a significant difference in mean total length between the samples from the two years ($\alpha < .001$, t-test). Length data from August for johnny darters, rainbow smelt, ninespine sticklebacks and white suckers were

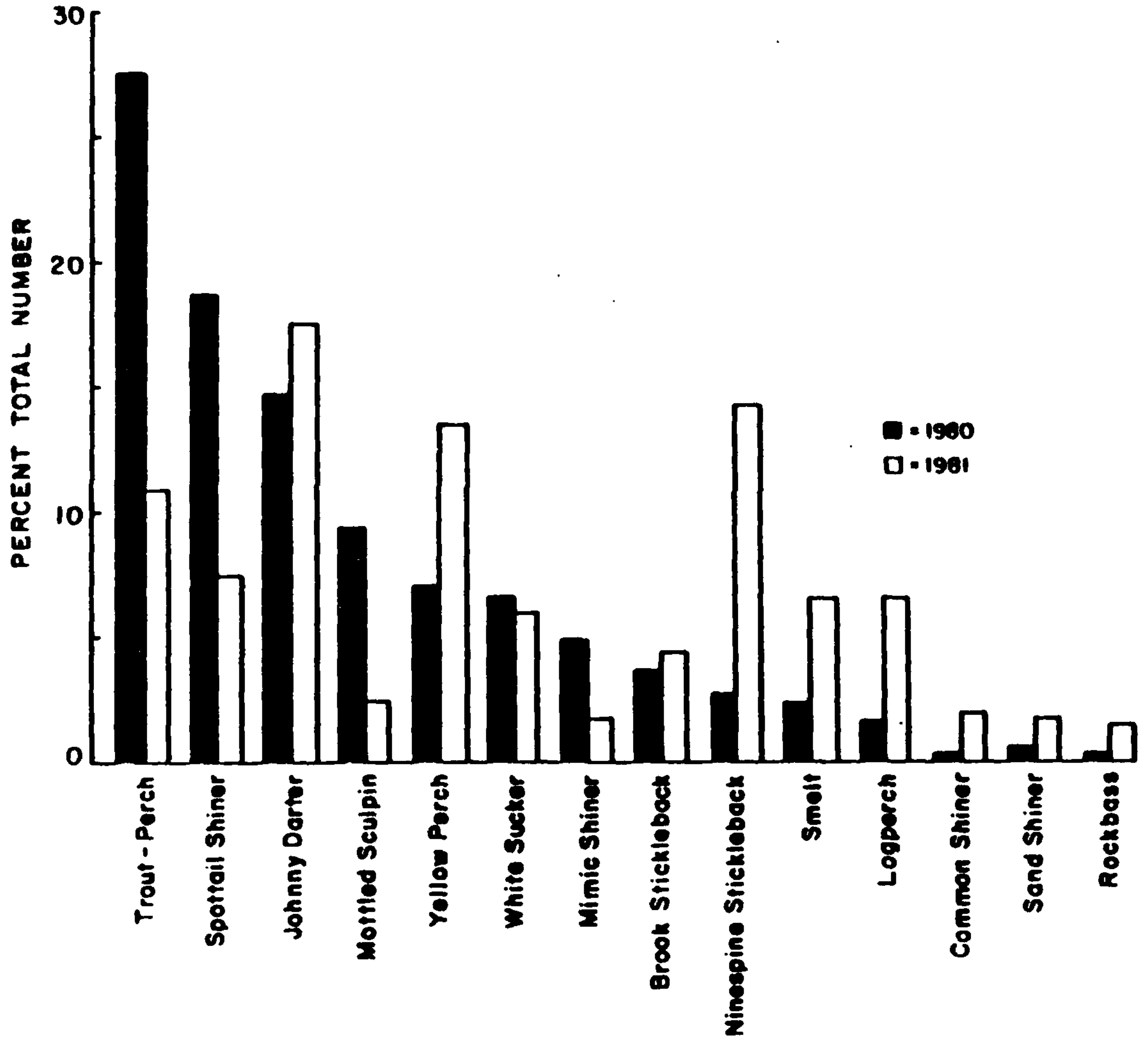


Figure 42. Percent of total number for the major species caught by trawl in navigation Courses 7 and 9 during the summer of 1980 and 1981.

analyzed and no annual differences were observed. Means and length ranges were nearly equal for the johnny darter, smelt and ninespine stickleback while the white sucker catch displayed such high variability that no difference could be shown. Length comparisons using other, commercially important species were not possible since capture of those species was mostly incidental, thus sample sizes were too small.

PHYSICAL AND CHEMICAL ASPECTS

Water Chemistry, Temperature and Turbidity

Water Temperature. Water temperatures at all study sites remained around $0^{o}C$ during winter, began rising in May, and reached maximum values of 19 - $24^{o}C$ in late summer (Table 37). Temperatures at all sites returned to near-freezing by late November. Annual temperature regimens were nearly identical in Course 5 and Middle Neebish Channel, with maximum values occurring in August. The study sites in Lake George, however, experienced higher maximum temperatures that extended further into the season (circa 5 September).

Summer and spring water temperatures in nearshore areas were higher than offshore areas when compared at all sites (Table 37). Conversely, offshore areas demonstrated higher average temperatures than did inshore areas in fall. Lake George was warmer than the other sites at both depths in spring and summer, but all sites had similar temperatures in fall.

Dissolved Oxygen. Dissolved oxygen content generally remained fairly constant at all sites during all seasons reported (Table 38). Nearshore and offshore values were comparable in most cases, except for Course 5 during summer which experienced the lowest dissolved oxygen concentrations nearshore. Of the total 298 dissolved oxygen measurements, only four were less than 70 percent saturation.

Turbidity. Average turbidity values were the greatest during fall at all sites (Table 39) while winter turbidity values were the lowest. With two exceptions, nearshore areas were more turbid than offshore areas at all sites during all seasons. Lake George experienced higher turbidities than the other sites for all seasons.

Dissolved Solids. Dissolved solids content remained the most constant water quality parameter at all sites (Table 40). Only 3 percent of the dissolved solids measurements were outside the 50 - 80 ppm (mg/l) range for the year.

pH. pH values were the least variable at all sites during spring (Table 41). Summer offshore pH values at all sites ranged towards more basic conditions while fall offshore pH values at all sites ranged towards more acidic conditions. No major differences between sites occurred.

Winter Sedimentation Rates

Average amounts of sediment collected at each station are presented in Table 42. Sediment samplers at a third station in Lake Nicolet were not

Table 37. Ranges and means of water temperatures taken at nearshore and offshore sites in Navigation Courses 5, 7 and 9, and Lake George, St. Marys River, 1981.

	Winter			Spring			Summer			Fall		
	n	$\bar{x}$	Range	n	$\bar{x}$	Range	n	$\bar{x}$	Range	n	$\bar{x}$	Range
Course 5												
Nearshore	--	--	--	12	7.2	1 to 14	6	19.3	15 to 21	13	9.7	3 to 17
Offshore	9	<0	<0 to 1.0	27	4.2	1 to 10	19	15.5	8 to 19	16	10.3	3 to 17
Lake George												
Nearshore	--	--	--	11	10.5	6 to 16	18	20.0	13 to 24	12	10.0	2 to 23
Offshore	--	--	--	22	7.1	4 to 12	21	17.6	10 to 21	18	11.0	2 to 18
Courses 7 and 9												
Nearshore	--	--	--	15	7.4	4 to 11	27	16.1	8 to 23	18	11.8	6 to 17
Offshore	11	<0	<0	41	4.4	1 to 9	39	14.3	8 to 22	29	12.2	5 to 18

Table 38. Ranges and means of dissolved oxygen measurements taken at nearshore and offshore sites in Navigation Courses 5, 7 and 9, and Lake George, St. Marys River, 1981.

	Spring			Summer			Fall		
	n	$\bar{x}$	Range	n	$\bar{x}$	Range	n	$\bar{x}$	Range
Course 5									
Nearshore	8	12.4	11.6 - 13.1	3	4.8	3.5 - 5.4	10	9.3	6.6 - 12.8
Offshore	22	12.4	10.4 - 13.9	19	9.7	9.1 - 11.4	15	11.6	9.2 - 13.0
Lake George									
Nearshore	6	10.4	9.2 - 12.6	10	8.2	6.4 - 9.4	8	10.9	8.7 - 13.2
Offshore	22	10.6	10.0 - 12.8	19	9.3	6.9 - 10.4	19	10.5	6.8 - 13.1
Courses 7 and 9									
Nearshore	8	12.0	11.1 - 13.2	15	9.3	8.1 - 10.8	15	10.5	8.8 - 11.8
Offshore	39	13.2	8.8 - 13.7	35	9.9	8.7 - 10.8	25	10.4	5.7 - 12.6

Table 39. Ranges and means of turbidity measurements taken at nearshore and offshore sites in Navigation Courses 5, 7 and 9, and Lake George, St. Marys River, 1981. (Units = ppm)

	Spring			Summer			Fall		
	n	$\bar{x}$	Range	n	$\bar{x}$	Range	n	$\bar{x}$	Range
Course 5									
Nearshore	12	6.1	1.6 - 15.0	10	1.9	1.3 - 2.2	12	6.2	2.0 - 28
Offshore	26	2.5	0.6 - 9.4	21	2.4	0.7 - 4.9	16	4.1	1.5 - 18
Lake George									
Nearshore	9	19.0	4.7 - 43.0	18	18.8	3.6 - 120.0	11	25.8	4.2 - 68
Offshore	21	5.3	1.8 - 26.0	21	3.5	1.7 - 6.9	19	4.5	1.5 - 12
Courses 7 and 9									
Nearshore	16	2.9	1.3 - 6.7	31	2.4	1.4 - 3.7	20	4.4	1.4 - 18
Offshore	46	1.6	0.6 - 3.9	42	2.4	1.2 - 6.8	27	2.9	1.4 - 23

Table 40. Weekly ranges of dissolved solids measurements from Navigation Courses 5, 7 and 9, and Lake George, St. Marys River, 1981.

Date	Course 5	Lake George	Courses 7 and 9
4/5 - 4/11	---	---	---
4/12 - 4/18	60 - 65	60	55 - 65
4/19 - 4/25	55 - 65	---	60 - 62
4/26 - 5/2	61 - 63	61	64 - 67
5/3 - 5/9	57 - 65	60 - 74	60
5/10 - 5/16	64 - 67	64 - 65	59 - 65
5/17 - 5/23	59 - 63	59 - 63	59 - 65
5/24 - 5/30	58	57 - 59	56 - 58
5/31 - 6/6	58 - 61	55 - 59	58 - 61
6/7 - 6/13	52 - 58	51 - 60	55 - 59
6/14 - 6/20	55	111	55
6/21 - 6/27	56 - 60	56 - 61	51 - 60
6/28 - 7/4	60	41 - 65	55 - 60
7/5 - 7/11	55 - 62	56 - 65	60 - 70
7/12 - 7/18	---	---	51 - 58
7/19 - 7/25	55 - 57	56 - 62	52 - 64
7/26 - 8/1	57	59 - 68	---
8/2 - 8/8	53 -150	60 - 63	52 -175
8/9 - 8/15	51 - 76	65 - 79	---
8/16 - 8/22	60 - 68	61 - 64	55 - 61
8/23 - 8/29	55 - 61	58 - 62	52 - 62
8/30 - 9/5	63	61 - 72	60 - 65
9/6 - 9/12	55 - 61	53 - 59	51 - 58
9/13 - 9/19	55 - 59	68 - 69	50 - 61
9/20 - 9/26	54 - 60	62	54 - 80
9/27 - 10/3	55 - 58	58 - 69	52 - 60
10/4 - 10/10	53 - 65	57 - 62	---

Continued

Table 40. (Concluded)

Date	Course 5	Lake George	Courses 7 and 9
10/11 - 10/17	55	56	52 - 65
10/18 - 10/24	49 - 142	69 - 70	---
10/25 - 10/31	62 - 65	22 - 112	---
11/1 - 11/7	---	---	62 - 158
11/8 - 11/14	70 - 121	132 - 138	---
11/15 - 11/21	---	---	62 - 71
11/22 - 11/28	---	---	
11/29 - 12/5	58 - 61	53 - 55	

Table 41. Ranges of pH measurements taken at nearshore and offshore sites in Navigation Courses 5, 7 and 9, and Lake George, St. Marys River, 1981.

	Spring	Summer	Fall
Course 5			
Nearshore	7.0 - 7.4	6.6 - 7.8	5.9 - 7.5
Offshore	7.1 - 7.4	6.6 - 8.2	4.9 - 7.1
Lake George			
Nearshore	7.2 - 7.5	6.6 - 7.7	6.2 - 9.2
Offshore	7.3 - 7.4	6.2 - 8.4	5.0 - 7.3
Courses 7 and 9			
Nearshore	7.0 - 7.4	6.2 - 7.7	5.7 - 7.4
Offshore	7.2 - 7.4	6.4 - 8.2	4.8 - 7.3

Table 42. Sediment accumulation rates in sediment traps placed in the St. Marys River during winter, 1981.

Location	Lake Nicolet		Navigation Course 7			Lake George		
Exposure period	Feb. 3 - Feb. 24		Feb. 8 - Mar. 2			Feb. 5 - Mar. 6		
Exposure (days)	21		22			29		
Station	1	2	1	2	3	1	2	3
Mg (dry wt.)/day	0.07	0.3	0.3	0.26	0.15	0.47	3.2	0.80
Mg/day/m^2	138.2	592.1	592.1	513.1	296.0	927.6	6,315.4	1,578.8
Exposure period	Feb. 24 - Mar. 20		Mar. 2 - Mar. 24			Mar. 6 - Mar. 23		
Exposure (days)	24		22			17		
Station	1	2	1	2	3	1	2	3
Mg (dry wt.)/day	0.19	0.68	0.45	0.32	0.15	0.32	---	0.60
Mg/day/m^2	374.9	1,342.0	888.1	631.54	296.0	631.54	---	1,184.1
Exposure period	Feb. 3 - Mar. 20		Feb. 8 - Mar. 24			Feb. 5 - Mar. 23		
Exposure (days)	45		44			46		
Station	1	2	1	2	3	1	2	3
Mg (dry wt.)/day	0.14	0.50	0.38	0.29	0.15	0.43	---	0.74
Mg/day/m^2	276.2	986.6	749.8	572.2	296.0	848.5	---	1,460.1
Inorganic fraction (%)	100.0	99.3	97.3	97.7	87.3	98.5	---	95.7

recovered because of loss of the station marker due to ice melt. Station 2 in Lake George was unaccessible for the second series due to an unusually early warming period creating treacherous ice conditions.

The sedimentation rate in Lake George was much higher than in either Lake Nicolet or Course 7 (Table 42). Although no turbidity measurements were taken during the winter in Lake George for comparison to the other areas, the west shore of Lake George near the sediment trap stations was visually much more turbid than either Course 7 or Lake Nicolet. Gleason et al. (1979) reported St. Marys River sedimentation rates an order of magnitude higher than found in this study during a winter with vessel passage. Those results may have been overestimated due to the very low aspect ratio of their traps, however.

The measured sediment flux during the first exposure period was lower in Lake Nicolet and Course 7 than during the second period, whereas Lake George demonstrated a decline in sedimentation between the first period to the second period (Table 42). A plot of turbidities in Lake Nicolet and Course 7 revealed generally lower turbidities during the first exposure period with a peak during the second exposure time around 10 March (Figure 43). This is commensurative with the sediment trap data, assuming sediment load is related to turbidity.

The only sediment collector returned after ice-out was from Station 2 in Lake Nicolet on 15 April. The others were either moved, covered up or not marked well enough to be found. The large amount of sediment had filled the trap and may have reduced the aspect ratio enough to cause the trap to over-collect. However, the large amount of sediment may be indicative of increased sedimentation associated with ice-out.

Ash-free weights of the sediment demonstrated a high inorganic content (Table 42). This is comparable to the organic-inorganic fractions of sediment collected in same areas of the St. Marys River by Gleason et al. (1979).

Sediment Chemistry of Shipping and Non-Shipping Channels

Manganese at Lake George west was the only incidence of a parameter exceeding U.S. Environmental Protection Agency Region V (1977) criteria for heavy pollution. Six parameters including total P, As, Cu, total Cr, Ni and Mn, were detected at moderately polluted levels a total of 17 times collectively (Tables 43 and 44). With two exceptions, these levels were confined to three sites: Lake George west, Lake Nicolet west and Lake Nicolet channel. The exceptions were Lake Nicolet east, which was moderately polluted with total Cr, and Cu levels in the Lake Nicolet channel which were lower than the "moderately polluted" criteria. All other values could be judged "non-polluted" by the 1977 USEPA criteria.

Lake George channel had the coarsest sediments, with 83.2% of the particles greater than 0.074 mm in diameter. Lake George east and Lake Nicolet channel were next in coarseness, with 54.7% and 28.3% of the particles greater than 0.074 mm in diameter, respectively. The remaining sites had much finer sediments, with 5% or less of the particles greater than 0.074 mm in diameter. Sediment character in both off-channel areas was predominantly clays with some silt, while the two channels had some sands mixed in as well (Table 45).

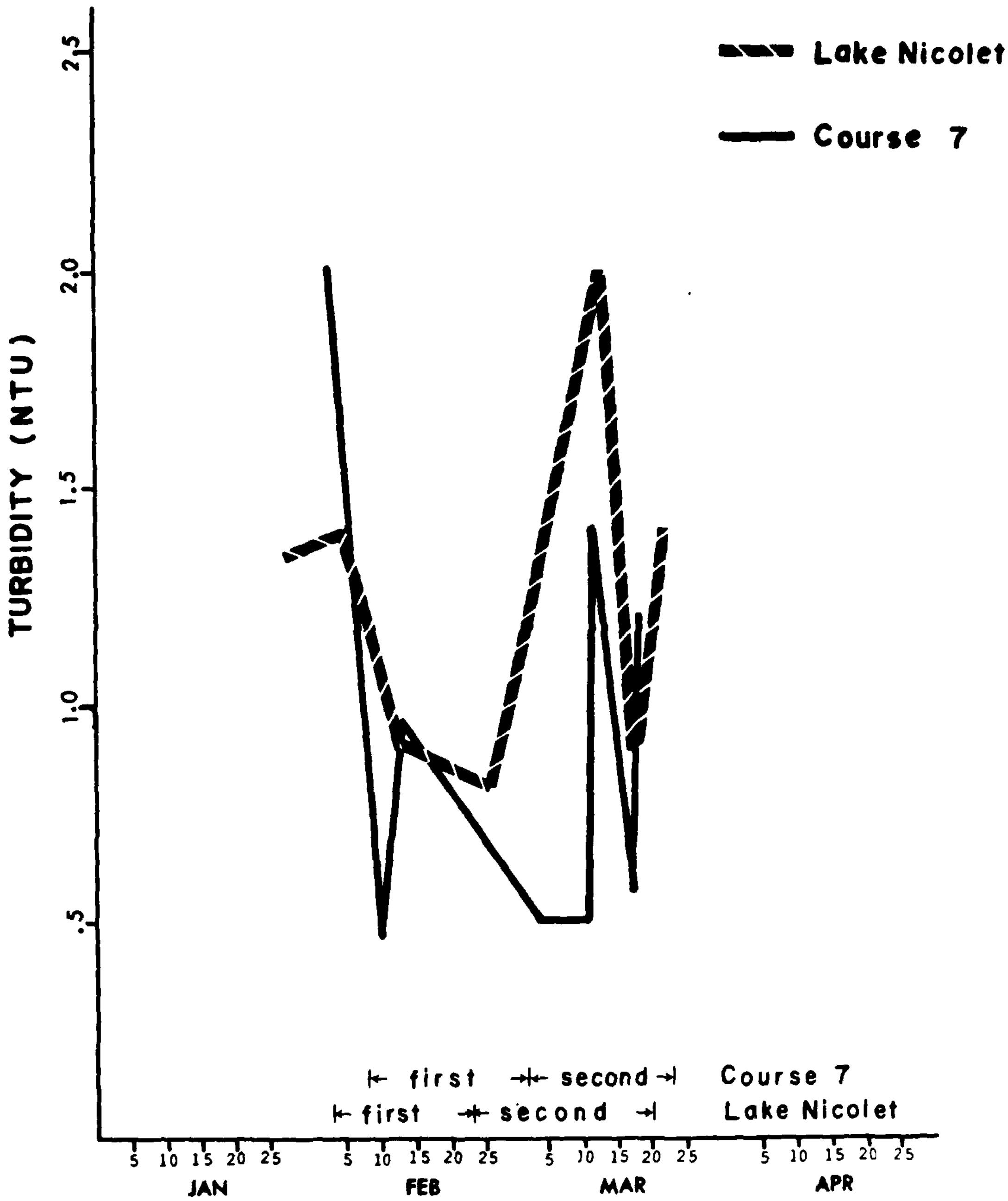


Figure 43. Turbidity readings during the first and second exposure periods of sediment traps in Lake Nicolet and Navigation Course 7.

Table 43. Nutrients, Heavy Metals and Organic Compounds in St. Marys River Sediments from the Lake George (Non-shipping) Channel Area (All Units mg/kg Dry Weight Except Total Solids)

	Lake George Channel			
Parameter	West	Channel	East	Mean
Total Solids (%)	55.2	39.7	54.1	49.7
Total Volatile Solids	22,300	6,800	13,000	14,033
COD	6,000	2,800	18,400	9,067
TKN	400	260	410	357
NH_3-N	17	19	31	22.3
Oil and Grease	180	210	280	223.3
Total CN	<1	<1	<1	-
Total P	540*	250	200	330
Hg	0.018	0.007	0.024	0.0163
As	4.0*	1.6	1.5	2.37
Cu	29*	6.3	7.8	14.37
Total Cr	34*	8.6	11	17.87
Pb	<4	<2	14	-
Zn	54	28	52	44.7
Fe	12,500	4,500	7,200	8,067
Ni	33*	4.3	6.5	14.6
Mn	540**	76	110	242
Cd	<0.3	<0.2	<0.2	-
Ba	<160	<90	<70	-
PCB				
Arochlor 1242	<0.1	<0.1	<0.1	-
Arochlor 1254	-	-	-	-
Arochlor 1260	0.1	0.06	0.06	0.073

* - exceeds USEPA Region V criteria (1977) for moderate pollution
** - exceeds USEPA Region V criteria (1977) for heavy pollution

Table 44. Nutrients, Heavy Metals and Organic Compounds in St. Marys River Sediments from the Lake Nicolet (Shipping) Channel Area (All Units mg/kg Dry Weight Except Total Solids)

Parameter	Lake Nicolet Channel			
	West	Channel	East	Mean
Total Solids (%)	47.2	51.6	57.0	51.9
Total Volatile Solids	25,000	24,200	21,600	23,600
COD	29,200	15,600	28,200	15,667
TKN	400	340	440	393
NH_3-N	19	30	31	26.7
Oil and Grease	190	79	230	166.3
Total CN	<1	<1	<1	-
Total P	420*	420*	270	370
Hg	0.009	0.007	0.019	0.0117
As	3.4*	3.1*	2.8	3.1
Cu	25*	21	15	20.3
Total Cr	36*	35*	46*	39
Pb	<4	<4	17	-
Zn	61	56	46	54.3
Fe	14,800	14,700	5,800	11,767
Ni	38*	23*	10	23.7
Mn	340*	350*	140	277
Cd	<0.2	<0.3	<0.2	-
Ba	<190	<170	<90	-
PCB				
Arochlor 1242	<0.1	<0.1	<0.1	-
Arochlor 1254	-	-	-	-
Arochlor 1260	0.1	0.07	0.08	0.083

* - exceeds USEPA Region V criteria (1977) for moderate pollution

Table 45. Particle size and character of St. Marys River sediments from a shipping and a non-shipping channel.

		Cumulative Percent Sediment Retained			Percent Passing	Character
Sieve Opening (mm)		0.35	0.167	0.074	0.074	
	West	0.5	0.9	2.5	97.5	compact, sticky clay
Lake George (non-shipping)	Channel	0.8	41.6	83.2	16.8	loose, fine sand with some shell fragments and organic matter
	East	0.1	30.4	54.7	45.3	clay with some silt
	West	0.3	1.8	2.7	97.3	clay and silt
Lake Nicolet (shipping)	Channel	2.5	17.0	28.3	71.7	clay and fine sand mix
	East	1.4	2.3	5.0	95.0	clay and silt

DISCUSSION

BENTHIC MACROINVERTEBRATES

Navigation Courses 7 and 9

The taxonomic composition of benthic invertebrates at Navigation Courses 7 and 9 of the Middle Neebish Channel in 1981 was similar to that found in 1979 (Liston et al. 1980). As in 1979, Chironomidae comprised the greatest proportion of invertebrates collected during 1981. Although Chironomidae were more abundant in 1981 samples than 1979, they comprised less (57.9%) of the total benthos than previously (63.8%) at these two stations. This apparent decrease in the predominance of Chironomidae larvae may be partly an artifact of sample handling. Both Nematoda and Ostracoda were quantified in 1981 samples, whereas the presence or absence of these groups was only noted in 1979 samples. Other major taxonomic groups which comprised greater than 5% of the total benthos included Oligochaeta, Ephemeroptera, and Ceratopogonidae. Each of these groups were approximately twice as common in 1981 samples than in 1979 samples. Conversely Isopoda, Gastropoda, and Pelecypoda were less common in 1981 than in 1979. Previous benthic studies of the St. Marys River have documented the presence of a similar taxonomic composition to that found during 1979 and 1981 (Veal 1968, Poe et al. 1979, Kenaga 1979). Each of these studies, however, varied in taxonomic treatment and consequently the taxonomic composition presented varies among the published reports.

Shifts in the predominant genera of Chironomidae were noted between years, but in all other major taxonomic groups, genera collected in 1979 were similar to those collected in 1981. *Polypedilum* sp. was the most common genus collected at Courses 7 and 9 in 1981, while in 1979 *Tribelos* sp. was uncommon and *Cricotopus* sp. was less common in 1981 compared to 1979. Other genera which were common in 1979 remained common in 1981, including *Ablabesmyia* sp., *Larsia* sp. and *Procladius* sp.

These shifts in generic composition of the Chironomidae do not appear to suggest a change in water quality from 1979 to 1981. Both *Tribelos* sp. and *Cricotopus* sp. have been reported to occur in eutrophic, mesotrophic or dystrophic waters (Beck 1977). Similarly, the most common chironomid larvae collected in 1981 characteristically occurs in mesotrophic waters. All of the above genera include species which are common in rivers and are typically epibenthic (living on the bottom, but not burrowing). In addition, all of the common genera collected during both 1979 and 1981 from Courses 7 and 9 are most frequently reported from waters of mesolichtophilus turbidity (generally clear, but occasionally clouded waters; Beck 1977).

Total benthic invertebrate abundance at Courses 7 and 9 was similar, although overall slightly greater in 1981 than in 1979. As in 1979, abundance within the navigation channel during 1981 was significantly less than outside the navigation channel. In comparing abundances among years, the greater numbers of benthos found at Course 7 during 1981 were not statistically significant. However, abundance of benthic invertebrates in spring 1979 were significantly less than in fall 1979 and during both seasons in 1981. In addition to Courses 7 and 9 comparisons of 1979 and 1981 data were also made for one station in Course 5. At this station total benthos collected during 1981 was 4 - 5 times that collected in 1979. Because of limited replication these data were not tested for statistical significance, however.

Navigation Course 5 and Lake George

A total of 98 taxa of benthic invertebrates were identified from Navigation Course 5 and Lake George combined. Of these, 59 occurred in each area, 16 were taken only from Lake George, and 23 were taken only from Course 5. All common taxa occurred in both areas, although they comprised different proportions of the total benthos in some cases.

In both systems, Chironomidae were the predominant benthic taxon. In Course 5 Chironomidae comprised 55.4% and 57.3% of the total benthos at the 3 m depth and in the littoral zone, respectively. Predominant taxa included Ablabesmyia sp. and Polypedilum sp. at the 3 m depth and Polypedilum sp., Paratanytarsus sp., Larsia sp. and Procladius sp. in the littoral zone. In Lake George, Chironomidae comprised less of the total benthos from both the 3 m depth and littoral zone (46.1% and 44.6%, respectively). Excepting Paratanytarsus sp., genera common in Lake George were the same as in Course 5.

Other common taxa in Course 5 included Oligochaeta, Amphipoda (Hyalella), Ephemeroptera (Ephemera and Hexagenia) and Ceratopogonidae at the 3 m depth. In the littoral zone, Oligochaeta, Ostracoda, Isopoda (Asellus), Amphipoda (Hyalella), and Ephemeroptera (Caenis) were common.

In Lake George, Ephemeroptera comprised a greater proportion of the total benthos in both the littoral zone and at the 3 m depth. The predominant genera offshore was Hexagenia sp., while in the littoral zone Caenis sp. was predominant. Seasonally, burrowing mayflies were twice as common in Lake George as in Course 5 ($995/m^2$ vs. $455/m^2$). Greater numbers of Hexagenia sp. in Lake George likely reflect greater organic content of Lake George sediments in comparison to Course 5 (Edmonds et al. 1976). Increasing numbers of Hexagenia prior to hypolimnetic oxygen depletion in Lake Erie has been attributed to organic enrichment (Brittain 1982).

Other notable differences in the taxonomic composition of these two systems included a greater proportion of mollusks in Lake George and a greater proportion of amphipods in Course 5. The high density of Sphaeriidae in Lake George compared to Course 5 is a response to slower water flow in Lake George. Pelecypoda are filter feeders which feed on plankton and organic detritus which is settling out of the water column. Slower water currents in Lake George allow finer particles to settle to the bottom enhancing conditions for the Sphaeriidae which are capable of filtering very fine particles (Pennak 1978).

Seasonal mean abundance of total benthic invertebrates was similar within the littoral zones of Course 5 and Lake George ($18,506/m^2$ and $17,915/m^2$, respectively). However, average seasonal abundance at the 3 m depth was greater in Course 5 ($13,771/m^2$) than Lake George ($9,084/m^2$). Comparison of these data utilizing a 4 X 5 contingency table indicated one could have confidence that samples were not drawn from the same population ($P < .01$). However, the distribution values above or below predicted values was not consistent. Each lake had monthly abundance values both above and below predicted.

In contrast to numerical abundance data, estimates of standing crop in biomass were greatest at the 3 m depth of Lake George. Standing crop biomass within the littoral zones of each area appeared to be similar, while lowest standing crop biomass was recorded from the 3 m depth station of Course 5. This resulted from the greater relative abundance of larger benthic organisms in Lake George, particularly Pelecypoda and Hexagenia sp.

Estimates of annual production in mg dry wt./m^2/yr appeared to be similar between areas when both littoral and offshore stations were considered. Although production estimates from the 3 m depth of Lake George were greatest, production data suggest the areas differ less than standing crop or abundance information alone would indicate. Furthermore, methods of estimating non-cohort production are designed to give estimates in the correct order of magnitude (Waters 1977). Therefore, slight differences should not be strictly interpreted. Production in Lake George is not as great as might be expected from standing crop data because the larger, more abundant taxa which are common in Lake George also have a longer turnover time. This is reflected in the annual production to mean biomass (P/B) ratio. High P/B ratios indicate more rapid turnover rates, while low P/B ratios reflect slower turnover rates (Barnes and Mann 1980). In the St. Marys River, Hexagenia is hemivoltine (two year life cycle) and Sphaeriidae are believed to live 12 - 18 months (Pennak 1978). These two taxa comprised most of the production in Lake George. In contrast, most of the production in Course 5 was comprised of Chironomidae some of which are univoltine and some multivoltine. Thus, although being smaller bodied most taxa from Course 5 achieve adulthood faster.

Little information on the total benthic community production for lakes exists because of the difficulty in sampling all cohorts of a variety of organisms. However, Barnes and Mann (1980) suggest benthic community production should be in the range of 100 - 1000 g/m^2/yr fresh weight. Assuming dry weight to be roughly 10% of wet weight, production estimates for the 15 common benthic invertebrates of Course 5 and Lake George fall within this range. Additionally, production estimates from other areas for similar taxa appear similar to those found in this study.

The effects on benthic invertebrate communities from an extended navigation season could be significant if excessive sediment loading and sedimentation occurred from eroded shore zones. Potential problems related to siltation and sediment character were outlined and discussed in an earlier report (Liston et al. 1980).

AQUATIC MACROPHYTES

Objectives of the 1981 aquatic plant studies on the St. Marys River have been met by the program considered above. The study provided quantitative data on the distribution and abundance of aquatic vegetation at selected sites adjacent to navigation channels of the river (Course 5 in Lake Nicolet and Course 7 of the Upbound Neebish Channel). Standard and repeatable techniques were used to record location and biomass of dominant forms of emergent and submersed vegetation during the ice-free season. Rootstock biomass of emergent plants, important for annual regeneration of photosynthetic shoots and for stabilizing shoreline sediments, was not studied. Development of concepts from the data regarding the annual growth and degeneration cycle of submersed plants was difficult because of lack of suitable quantitative data. Hand-sampling techniques were developed for obtaining biomass in submersed plant beds. A standard procedure was established for converting data obtained from submersed beds by PONAR dredge to hand-sampled equivalents. Beds of submersed plants found at the edge of the Upbound Neebish Channel in 1979 were found in the same locations in 1981. The same species dominated these beds in both years, and at similar biomass. They have a perennial habit, and are a characteristic of the river system that reflects the present condition of the quality of the environment. For example, charophytes and quillworts tend not to dominate the submersed vegetation of eutrophic lakes and streams.

The St. Marys River system is large relative to the number and area of sites for which data has been obtained thus far in studies. Never-the-less, patterns are emerging from the record to date, and these patterns infer that processes are at work to cause them. The validity of interpretations of these patterns needs to be tested before baseline information on aquatic vegetation of the system becomes sufficiently complete for valid judgements regarding impacts of various uses of the river. One pattern that merits discussion is the observed lack of consistency in the time at which dominant species of aquatic plants germinate, achieve their maximum growth rates, and attain their annual maximum biomass. These varied among sites used in this study. We postulate that water temperature controlled growth in a way that was specifically tied to the relationship of this river to Lake Superior. The lake served as a vast reservoir of water of low heat content. The amount of heat in the St. Marys River in the growing season was dependent on the heat characteristics of Lake Superior water moving downstream, and the residence time for heat accumulation while that water was in portions of the river itself. Because residence times varied among parts of the river system, horizontal temperature gradients were characteristic of the environment. These gradients were steep (5 - 15°C) between channels and adjacent emergent plant beds throughout the growing season.

The most obvious example from the data on control by heat on timing of germination, timing of maximum growth rate, and timing of maximum annual biomass was in beds of emergent vegetation. Centers of cell division and growth (meristems) in the dominant emergent plants of the St. Marys River were all submerged. Shoots of *Scirpus acutus*, *Scirpus* *-mericanus*, *Eleocharis smallii*, and *Equisetum fluviatile* grew primarily from a region at their base. On transects of this study, inshore shoots of these plants germinated in the hydrosoil and emerged from shallows in mid to late May. Shoots in offshore portions of beds of the same species germinated later and emerged in mid to

late June. Perusal of temperature records kept in portions of this study dealing with collections of fishes and invertebrates, and field observations of plants, suggested that the threshold for germination of shoots from rhizomes of Scirpus acutus and Scirpus americanus was in the range of 5 - 7°C. Using temperature records, which showed typical horizontal gradients across plant beds, on the order of one degree-day (0.8 - 1.2) above threshold was required per centimeter of water depth for shoots to emerge through the surface of the water. It is doubtless that this mechanism explains the commonly observed progression of plant emergence from shallow shoreward areas outward in wetlands adjacent to the river. The concept suggests there is a time-predictable, temperature-controlled process at work which creates cover and a food supply (via periphyton) that fish-food organisms and fish may very well find important in the array of environmental cues that serve their survival.

Other cases of heat control on plant growth are more obscure in the data. However, annual maximum biomass of shoots was present in the emergent stand on Lake George after 15 July in 1981 (Figure 22), while it occurred after 20 August on the study site in Lake Nicolet (Figure 23). While the difference in time of maximum biomass may have been due to other factors (e.g. species differences between Scirpus acutus and S. americanus, availability of nutrients, force of waves and currents), we propose that differences in available heat had an over riding influence on determining it. Because of their basal growth habit, dominant plants likely did not escape the effect of water temperature on biomass accumulation after shoots emerged into the atmosphere that was relatively homothermal between study sites. Water in Lake George was substantially warmer over inshore areas during the growing season than water over similar areas in Lake Nicolet (Figure 24). The tendency for colder offshore water in Lake George to circulate into the study site and influence growth in basal meristems was minimized by protection of the site from prevailing winds. The transect on Lake George had a west shore location. The Lake Nicolet transect was exposed in this regard. Prevailing winds blew toward its east shore location across cold water carried downstream through the lake. From these observations, we propose that the difference in the time in the growing season at which dominant emergent plants on these transects reached maximum biomass was primarily a function of water temperature and heat. We predict that emergent plants on exposed sites, in terms of water circulation patterns, have maturity delayed relative to those that occupy protected sites in the same reach of the river. This prediction has potential significance in regard to growth on animal species as well as plants.

A comparison of data from beds of Isoetes riparia in Lake George and along Course 7 suggests that maturation of submersed beds was also different because of differences in the amounts of heat available as the growing season progressed. Recruitment of young plants in the warmer water in Lake George was first observed in July 1981 (Table B3). In colder water over the transect in Course 7, these plants first showed in collections one month later (Table B8). New recruits appeared at both sites shortly after the period in which water temperature rose rapidly to the plateau of maximum annual temperature shown in Figure 24. A relatively large contribution by perennial tissue to measurements of biomass in Isoetes beds precluded searching the data for correlations between heat and biomass for this species. The case for charophyte response to increasing heat was similarly obscured by the mixture of over-wintering and

new tissues in biomass samples. However, from observations of the presence of new tissue in samples, growth of Isoetes riparia and charophytes on transects in Lake Nicolet and along Course 7 appeared most rapid in July and August of 1981. Water temperatures over these submersed beds rose in that interval from 9 - 10°C in early July to a plateau of 18 - 19°C during the last two weeks of August. Accelerated growth rates were expected with these conditions. Water temperature undoubtedly controlled the time of germination, the time of maximum growth rate, and the time of occurrence of maximum annual biomass in submersed plants as well as emergents. Because of circulation patterns, temperature differences among submerged sites (2.0 - 7.0 m depth) in any particular reach of the river were likely smaller than differences between protected and exposed emergent sites in the same reach. For the system as a whole, Lake George data compared with that for Lake Nicolet and Course 7 showed that important temperature differences did occur among submersed beds, and that maturation occurred earlier where heat content of the water during the growing season was higher. The best estimate from this study for time of seasonal maxima in biomass for Isoetes riparia and charophyte beds in the relatively cold water in the Neebish Island region was September 1 - 10. This was a late maturation date; water temperature began to drop toward annual minima before this interval was over.

From this study it was apparent that horizontal temperature gradients profoundly influenced aquatic plant development in the St. Marys River. The degree-day concept was applied here to the growth of emergent plants across temperature and depth gradients that existed on study sites. The result illustrates the influence of heat. An emergent plant bed on a site protected from circulation of cold offshore water developed maximum biomass in the first one-half of July (Lake George). This is the habit of species dominating regional inland wetlands of comparable type. An emergent bed on an exposed site had development of maximum biomass delayed until late August or early September (Lake Nicolet). Submersed plant beds adjacent to channels of the main stem of the river also developed late (Lake Nicolet and Course 7). Their growing season was short relative to aquatic environments of temperate North America as a whole. The submersed plant growing season was longer by several weeks on a site remote from the principle channels of flow (Lake George). The character of Lake Superior's annual heat budget, and the rate of dispersal of Lake Superior water to portions of the river system, were principle factors causing the unusual array of heat regimes that existed in the St. Marys River. These heat regimes need careful documentation; the distribution of heat energy keys events that are important in understanding the biological resources of the system.

ICHTHYOPLANKTON

The seasonal succession, species composition, and abundance of fish larvae in the St. Marys River, as evidenced by the 1979, 1980 and 1981 ichthyoplankton collections, are similar to that seen in other investigations in the Great Lakes and northern temperate lakes, where larvae abundance increases as the water temperature increases rapidly (Faber 1967; Amundrud et al. 1974). As discussed in an earlier report, the fish community of the St. Marys River is essentially that of a percid community in a mesotrophic lake as described by Ryder and Kerr (1978), with walleye, northern pike, yellow perch, white sucker, burbot,

lake whitefish, cisco, sculpins, minnows, darters and trout-perch as primary components. Larvae of the majority of these species, with the exception of walleye and northern pike, were commonly collected. In addition, alewife and rainbow smelt larvae were also common and abundant in ichthyoplankton collections. Adult walleye and northern pike are frequently collected in the St. Marys River, so the absence of larvae in collections probably reflects either unsuitable spawning or nursery areas in the areas sampled, and the lack of sampling in the very shallow marshy littoral areas where northern pike larvae occur. Qualitative samples in the spring of 1980 yielded pike eggs and larvae, and large numbers of spawning adults were seen in a littoral marsh north of the Dunbar Research Station.

The spawning habits and spawning site preferences of fish species in the St. Marys River were outlined in an earlier report (Liston et al. 1980). Since few species in this system are pelagic spawners, it was suggested that the origin of the larvae in the collections from the navigation channel might be from upstream and adjacent littoral areas of the river, as well as from Lake Superior or Whitefish Bay. The results of sampling the shallow littoral areas in 1980 and 1981 support the hypothesis of the littoral origin of many of the fish larvae. Although species composition did not vary significantly from the inshore to offshore stations, abundance or density of larvae was considerably higher inshore. The importance of the shallow littoral areas as spawning and nursery areas for fish is continuously emphasized but few methods are available to quantitatively estimate abundance of larvae in vegetated areas. The methods employed in this study permit a comparison of relative abundance and density of individual taxa in different habitats, if the inherent limitations specific to each gear type as well as in the specific biology of the organisms (gear avoidance, patchiness, diel migrations) are remembered. Time of sample collection can influence species composition, particularly where a species, such as sculpin (Cottus sp.) or suckers exhibit nocturnal drift which often peaks after midnight either for dispersal or to facilitate feeding (Heard 1965; Geen et al. 1966; Sheldon 1968; Sinclair 1968; Clifford 1972; McCormick et al. 1977; Gale and Mohr 1978). In the St. Marys River, sampling time can affect both numbers and species composition of larval fish (Ashton, unpublished data). In the collections at Station 9 on 7 July 1981, the largest numbers of sucker and sculpin larvae were taken and all collections were made after midnight.

The appearance of large numbers of larvae in the shallow littoral zones, as well as their appearance at an earlier time than in the channel collections, is undoubtedly a function of where the eggs are spawned which is related to water temperature. Water temperatures were consistently warmer in the shallow areas at all stations.

Larvae of fall and winter spawners collected in the St. Marys River include burbot, fourhorn sculpin, cisco, and lake whitefish. The coregonid larvae utilize the warmer littoral areas shortly after ice-out, prior to regrowth of vegetation. Coregonid larvae have exhibited a seven fold increase in feeding at water temperatures from 5.3 to 12°C (Braum 1967), and warmer water temperature of the shallow littoral areas may be a significant survival factor for this species. The majority of larvae of burbot and fourhorn sculpin were yolk-sac larvae, and would be passive components of the plankton, possibly originating in Lake Superior.

Larvae of spring spawners include rainbow smelt, yellow perch, suckers and sculpins. Other taxa, such as logperch, johnny darter, cyprinids, carp, sunfishes and alewife spawn in early to late summer.

The assessment of impact of habitat alteration on the shallow littoral spawning and nursery areas of fish is tenuous, and potential impacts of excessive sedimentation have been discussed in detail elsewhere (Liston et al. 1980, 1981). These include direct effects on eggs and larvae, such as siltation, abrasion, increased turbidity and reduced visibility, and possible reduction in dissolved oxygen concentration. Indirect effects are more subtle, and may include changes in food availability or capture, decreased growth rates, increased susceptibility to predation, and changes in emigration or immigration to and from suitable nursery areas. Any direct or indirect effects are super-imposed upon natural stresses and mortality.

The most obvious impact from navigation, both winter and summer, is a physical one, where eggs and/or larvae are subject to dislodgement by water currents induced during vessel passage. Similarly, prey organisms may also be transported in and out of an area as may be organic matter or detritus. The extent of transport of larvae caused by vessel passage is unknown, as is the potential increased energy costs of maintaining or returning to a desired position or habitat. Similarly, the effects of such water movements on primary productivity of periphyton is also unknown. Increased circulation of nearshore waters may be beneficial in terms of supplying nutrients, preventing extreme temperatures, and increasing oxygen concentrations during darkness.

Patchiness is a characteristic of the distribution of larval fish, as well as a characteristic of the nature of the habitats (i.e. plant types) in the shallow littoral zone. Patchiness is recognized by most field ecologists (Levin and Paine 1974) and patch formation is often considered the product of random localized disturbances which reoccur but are unpredictable (Wiens 1976). The recurrent disturbance of an environment may provide a temporal gradient of various successional stages, resulting most often in an increased species diversity (Levin 1976). In aquatic systems, patch forming mechanisms may include severe storms, ice scour, and flooding.

A closer examination of specific features and functional aspects of spawning and nursery areas could aid future predictions of impacts from extended season navigation. Factors affecting growth rates of fish during early life stages (temperature, food availability, energy expenditure) could be examined in laboratory studies and related in field conditions in the St. Marys River. Similarly, laboratory studies of the effects of siltation on eggs and turbidity on larvae, using local species and bottom sediments, could be initiated. Food habits of the larvae along with abundance and quality of prey could be used to define suitability of nursery areas and in predicting losses in fish production in areas of the littoral zone that may be lost or jeopardized. The relationship between primary producers and invertebrates could be examined, as this is related to success of the early life stages of fish. Increased disturbance caused by vessel passage may have more of an effect on the primary producers of a community than on prey species and result in an indirect effect on the larval fish.

Assessment of annual variation in abundance of larval fish in the St. Marys River is confounded by a number of factors, both biotic and abiotic. Patchiness induces high variability in estimates of numbers in replicate samples at the same station on the same date and hampers comparison among stations sampled at different times of day (another known variable). Comparison between years is best approached looking at relative abundance and species composition of the ichthyoplankton. Assessment of the success of a year class can be determined using data from adult and juvenile fish collections and relating survival to factors such as weather, temperature, and abundance estimates of larvae.

JUVENILE AND ADULT FISH

Gill Nets

This study was contracted mainly to expand the data base for the St. Marys River near Neebish Island to aid in determining environmental effects of winter navigation-related activities (i.e. icebreaking, ship movements). The 1980 fish sampling was directed at determining horizontal distribution of fish in an open lake (Navigation Course 9) and narrow channel (Navigation Course 7) habitat. Goals of the 1981 sampling effort were: 1) an additional year's replication of sites sampled in 1980 to yield data for annual variation comparisons; and 2) make comparisons between a shipped (Lake Nicolet) and non-shipped (Lake George) habitat.

Liston et al. (1981) defined the three zones encountered from shoreline to the ship channel, stating that the fish community of the deep and shallow water habitats are similar. Bottom gill nets were primarily employed to sample the more mobile portion of the fish community occupying this section of the river. Species selectively sampled with gill nets in the St. Marys River include white sucker, cisco, northern pike, yellow perch, walleye, rock bass, burbot and rainbow smelt.

White Sucker. White sucker dominated the gill net collections comprising 26.9 and 25.5% of the winter and open water catches, respectively. Catch per effort was lower during winter (CPE 3.1) compared to CPE during open water (CPE 5.8) in the navigated portion of the St. Marys. Catch per effort was higher (7.1 vs. 5.8) in a non-shipped portion of the river (Lake George) than in a section exposed to ship traffic.

White suckers commonly inhabit shallow nearshore areas reaching highest abundance in shallow bays and near shoals in the Great Lakes (Koehler 1979; Lawrie 1978; Galloway and Kevern 1976). Incidence of white sucker in 1981 catches increased substantially over 1980 during winter. Catch increases occurred primarily at Navigation Course 7 in February and cannot be attributed to change in sites fished between years (Lake Munuscong was not sampled in 1981).

Age-length data recorded from cross-sectioned pectoral fin rays by Koehler (1979) indicated the bulk of our winter catch to be between 5 and 8 years old. Sexual maturity appears to be attained at ages of 4 or 5 years. Growth after maturity is substantially slowed (Koehler 1979; Beamish and Harvey 1969).

The dominance of female white sucker in winter collections in 1980 continued in 1981. Their frequency in winter samples was determined to be a function of activity rather than abundance since white sucker sex ratios from open water collections were nearly equal. Females appear to be more mobile during winter.

Catch per effort comparisons for Navigation Courses 5, 7 and 9 indicated suckers to be concentrated in the shallow water zone during darkness. Diel movement of white sucker into shallow water to engage in feeding has been documented (Kavaliers 1980; Anderson 1979; Koehler 1979; Spoor and Schloemer 1938). White sucker were collected at highest frequency during open water in Navigation Course 5. Food habit data indicate major dietary components to be chironomids (larvae and pupae) and cladocerans (Koehler 1979; Campbell 1935), both found in association with the extensive emergent vegetation growing at this site.

Age-length analyses done by Koehler (1979) suggest the bulk of the open water sample to be composed of age 3 to 9 fish. It is also important to note that gill net samples in Lake Nicolet had a lower overall catch per effort but a higher frequency of one and two year old fish in contrast to the Lake George catch.

Available food habits data (Koehler 1979) and gross inspection of stomach contents from collections indicate them to be browsing shallow water bottom feeders. Their numbers and ubiquitous occurrence within the St. Marys suggest white sucker are a readily available forage item. Inspection of osprey nest sites in the Neebish Island area revealed white sucker to be a major component of their diet. The importance of white sucker in transfer of energy between trophic levels is judged to be significant.

Cisco. Cisco were collected almost exclusively with gill nets and were secondary dominants in samples. Cisco comprised 35.5 and 21.9% of the under ice and open water catches, respectively. Catch per effort was lower during winter (CPE 2.6) than open water (CPE 4.9) sampling. Catch per effort for Lake George cisco collections was lower than Lake Nicolet cisco catch per effort (CPE 0.8 vs. CPE 2.3).

The substantial increase in the under ice catch of cisco in 1981 resulted in the near doubling of catch per effort over the 1980 value. A thaw in mid-February and ice breakup in late March may have been responsible for the catch increase in 1981 by elevating both zooplankton and fish activity. Liston et al. (1981) recorded copepods as both volumetric and numerical dominants in winter and summer cisco diets. Winter data suggest cisco move primarily along the ship channel margin in the St. Marys River. Cisco were more numerous in the shallow catches at Courses 7 and 9 during open water sampling.

Cisco in Pallette Lake, Wisconsin were found to undertake seasonal offshore/onshore migrations in response to increasing or decreasing water temperature (Engle and Magnuson 1976). Distribution and fluctuations in St. Marys River collections have been attributed to the combined influences of food availability and water temperature (Liston et al. 1981). Peak catches of cisco during open water in July were associated with feeding on emerging

Hexagenia sp. (Liston et al. 1981). Maximum lethal temperature limits of 20° and 26°C have been set for mature and young-of-the-year cisco, respectively (Colby and Brooke 1969, Edsall and Colby 1970). Absence of fish in samples in late July and August at water temperatures near 20°C support these data.

Near absence of cisco in gill net collections in Lake George was attributed to a combination of avoidance of elevated temperature during summer and high turbidity at this site limiting feeding success (Wilber 1971). Janssen (1978) observed cisco to be sight feeders ingesting food items from the water column and substrate in a particulate manner. Benthos data indicate the substrate is harder in Lake George as suggested by the dominance of *Ephemera* sp. in benthic collections of burrowing mayflies. Turbidity was also higher at this site than the navigated portions of the river. These data suggest that energy expended during search and feeding may be extreme, possibly serving as the causative agent restricting distribution in Lake George.

Gill net captured cisco ranged from 213 - 415 mm TL during winter and 108 - 482 mm TL during open water sampling. Ages for winter captured fish ranged from 3 - 11 years with most fish age 3 - 7. Cisco ages from open water collections ranged from 1 - 9 years. The majority of the catch was between 5 and 7 years with older fish infrequent occurrents.

Annual comparisons of catch per effort during open water sampling in 1980 and 1981 revealed catches of cisco declined in 1981. Three and four year olds (288 - 302 mm TL) and fish of ages 5 - 6 predominated in 1980 collections. Fish of ages 5 - 7 were noted with highest frequency in 1981 indicating the continued dominance of these year classes in the population.

Northern Pike. Northern pike were common in gill net collections contributing 4.5% to under ice and 11.9% to open water catches in the navigated portion of the St. Marys. Roughly 22% of the catch in Lake George consisted of pike. Catch per effort was lowest in winter (CPE 0.3) and highest in the non-shipped section of the river during open water (Lake George CPE 5.1 vs. Lake Nicolet CPE 2.6).

Northern pike were taken in highest relative frequency at netting stations where extensive growths of *Potamogeton* sp. were in evidence during both under ice and open water sampling. These stands are similarly distributed between the deep and shallow netting sites in Course 7. The majority of *Potamogeton* sp. in Course 9 exists at the deep net site. Northern pike are documented to be an "ambush predator" remaining in stationary concealment for prey and are hypothesized to be concentrated near these beds for concealment (Keast and Webb 1966).

Annual comparisons of northern pike winter catch per effort indicated a decline in 1981. Liston et al. (1981) stated that northern pike were commonly caught at Course 7 and Lake Munuscong (Rocky Point). The Lake Munuscong sample site was not fished in 1981, but sampling in 1982 at Rocky Point revealed a number of pike in the catch.

Pike captured during under ice work in both 1980 and 1981 were almost exclusively female. This sex ratio was much higher than values recorded from a winter sport fishery by Pearce (1961) of 2.4:1 and Dunning et al. (1978) of

5.7:1 for size limits of 508 and 660 mm TL, respectively. The 1980 data list two modes for pike captured during winter and open water. Winter data in 1981 listed a mode centered at 620 mm TL (age 5 - 6 for females). Dunning and Ross (1982) showed that from age 4 (508 mm TL) on, egg production is maximized for northern pike. Wright and Schorffaar (1976) recorded the St. Marys pike population to be slower growing with pike of 508 mm 5 years old. Our data indicate this size fish to be 4 - 6 years old. Our data indicate that female northern pike exhibit more pronounced movement than males in winter. The literature presented suggests that this increased movement may be in response to greater maintenance and gonadal maturation energy requirements.

A greater proportion of empty stomachs was noted for winter stomachs examined in 1980 (Liston et al. 1981). Mechanisms for continued growth during winter temperature minima at low levels of food intake has been postulated (Diana 1979; Diana and Mackey 1979; Keast 1968).

Northern pike length frequencies in open water collections from Lake Nicolet and Lake George were roughly identical with nearly 90% of the catch consisting of fish age 4 - 7. Females grew larger and lived longer than males. Lake George pike collections were higher (as stated previously) as a function of the more abundant stands of submersed vegetation at the sample site.

Pike were one of two species exhibiting catch per effort increase in 1981 during open water. More large fish were taken in 1981 samples. The mode remained at 480 mm TL during both years.

Yellow Perch. Yellow perch were the third most abundant species collected in bottom gill nets comprising 6.5 and 17.2% of the catch during winter and open water sampling, respectively. Catch per effort was lowest during under ice sampling (CPE 0.5). Catch per effort was higher in a non-shipped portion of the river (Lake George)(CPE 4.7) than in a section exposed to ship traffic (CPE 3.8).

Yellow perch were captured exclusively at Course 7 during under-ice sampling in 1981. Most of the yellow perch collected in 1980 (13 of 15) were also captured at this site in winter. Females dominated the winter catch in both years. The 1981 catch per effort value exhibited a modest increase over the 1980 under ice value (CPE 0.5 vs. 0.4).

Interval shifts in length frequency peaks between years were either a function of dominant age classes moving through the population or increased age specific mortality in these length frequency intervals.

Yellow perch evidenced higher catch per effort values in the shallow nets at both Courses 7 and 9 during open water sampling. Day/night, offshore/onshore migrations of yellow perch were recorded in Pallette Lake, Wisconsin (Engle and Magnuson 1976). Ages of yellow perch ranged from 1 to 10 years. The bulk of the catch was age 3 to 8 with the mode dominated by 4 - 6 year old fish.

Lake George perch collections were higher, probably as a consequence of higher concentrations of forage fish (see trap net section) and more extensive

beds of both emergent and submersed macrophytes providing both cover and food. Fish are an important volumetric contributor to the diet of adult perch (Liston et al. 1981; Ney 1978; Brazo 1973).

Immature and young adult perch are found primarily in association with vegetation during open water (Hergenrader and Hasler 1968). The more abundant submersed vegetation found at the Lake George sample site would explain the higher frequency of <180 mm TL fish in comparisons made with Lake Nicolet yellow perch length frequencies. Ferguson (1958) recorded preferred temperatures of 21 - 24.2°C for yellow perch. These temperatures commonly occur in Lake George for extended periods during open water.

Roughly equivalent values for catch per effort, and similar dispersion and configuration of between year length frequency comparisons indicate no marked fluctuations in the yellow perch population to date.

Walleye. Only one walleye was captured during winter sampling in 1981. This fish was captured in Course 7. Catch per effort decline in 1980 - 81 winter comparisons was primarily a function of different areas fished. The majority of walleye captured in 1980 were taken from the Lake Munuscong sample site during winter. This site was not sampled in 1981.

Walleye were more abundant during summer, contributing 7.6% to the open water catch. Open water catch per effort for walleye was higher in Lake Nicolet (CPE 1.7) than Lake George (CPE .9). Data suggest a preference for shallow water during the sample period (sunset to sunrise) at all sample sites for walleye. Crepuscular activity and nocturnal movement along the shoreline during feeding are well documented (Ney 1978; Kitchell et al. 1977; Priegel 1970).

The majority of the open water walleye catch was between 401 and 560 mm TL. Age data from Wright and Schorffaar (1976) and Miller (1981) indicate walleye of these lengths to be 5 to 7+ years old in the St. Marys. Miller (1981) stated that average walleye growth rates for all areas of the St. Marys sampled were well below the state average, but walleye older than age 6 exceeded the average growth.

Food habits of walleye in the St. Marys agree with those recorded by Ryder and Kerr (1978). Walleye stomachs taken from collections in Lake George contained a number of trout-perch, an item not recorded in stomachs captured elsewhere in the system. Trout-perch are abundant in Lake George (see trawl section) and are probably a readily available forage item.

Walleye showed an increase in the 1981 catch compared to 1980 values recorded during open water sampling. Large numbers of walleye were taken in Course 5 in 1981. This area was not sampled in 1980 with gill nets. The broader range and change in mode for the length frequency distribution in 1981 is primarily a function of increased sample size.

Rock Bass. Rock bass were abundant in winter collections from the St. Marys River in 1980 and 1981. Rock bass contributed 7.6 and 6.9% of the open water catch from the navigated portion of the St. Marys and Lake George,

respectively. Catch per effort was nearly equal for both areas. The nearshore nets at Courses 5 and 9 yielded highest catches, as did the nearshore net in Lake George. Rock bass grew longer and exhibited a greater range in length frequency in the navigated section of the St. Marys.

Catch per effort was higher for rock bass captured in 1980. The range in the length frequency distribution was slightly broader in 1981 and peaks occurred at longer intervals.

Rock bass feed primarily on insects found in association with the shoreline vegetation found in the St. Marys River (Keast and Webb 1966; Keast 1965). Large rock bass (<150 mm) feed primarily on crayfish. This agrees with work done by Keast and Webb (1966). Diel feeding periodicity of rock bass was studied by Keast and Webb (1968) who found feeding periods occurred at dawn and dusk. These periods were thought to coincide with increased activity of prey increasing fish feeding success.

Burbot. Burbot were primarily captured during under ice sampling and contributed 4.5% to the catch. Burbot were captured primarily in Course 5 in net panels nearest the ship channel. Lengths ranged from 410 to 648 mm TL with corresponding ages of 5 to 10 recorded.

Of the 14 burbot collected during winter, 12 were females. Burbot have been documented to enter rivers to spawn during water temperature minima (Lawler 1963). Spawning occurs around February in the St. Marys. Egg production ranged from 300,000 for a 410 mm (age IV) fish to 890,000 eggs for a 648 mm (age IX) fish.

Burbot were found to feed primarily on macroinvertebrates (*Mysis relicta* and crayfish) and fish in Lakes Superior and Erie by Bailey (1972) and Clemens (1951).

Potential Effects of Winter Navigation Activities. Fish population abundance in a given water body is a function of immigration and emigration, age-specific fecundity and death rates, and hatching success (Ricker 1975). Ice breaking and ship passage through the St. Marys River during the extension project could potentially affect fish populations in several ways. Physiological processes such as respiration, growth, reproduction, development and maturation may be altered. Changes in movement patterns, spatial and temporal abundance, alteration of habitats and changes in linkage and structure of the supporting food web are possible.

The St. Marys system is currently exposed to environmental perturbations associated with maintaining the navigation channel in its present state such as maintenance dredging, regulation of flows, and disturbance associated with vessel passage. Our data suggest Lake George to be a more productive environment than Lake Nicolet. Catches were consistently higher for most species in Lake George during open water sampling. Miller (1981) and Wright and Schorffaar (1976) both found growth rates to be below the state average in the St. Marys River for sport fish species. The method of calculating state wide average growth was unknown and may be skewed upward by inclusion of more data from warmer more productive waters from the southern portion of the state, however.

If this is not the case, a change in growth rates may be affected as a consequence of shipping. The degree of the effect would be a function of exposure duration and life stages of fish exposed. The response of the population may also be a function of intrinsic features, and stability and productivity of the environment (McFadden 1976; 1977).

Ice breaking activities and ship movements during winter could increase turbidity and possibly sediment load. A decrease in walleye recruitment was correlated with turbidity increase in Saginaw Bay by Schneider and Leach (1977). El-Zarka (1959) found growth rates to be negatively correlated with turbidity for young-of-the-year yellow perch. Correlation does not imply a direct cause and effect relationship between variables but simply is an indication of covariance. Also, responses observed by fish are quite likely a function of suspended sediments since turbidity is an optical property of water. Suspended sediment levels have been documented to affect fish, though very high concentrations are normally required to produce significant damage. Fine particles of suspended sediment can coat fish gills and at high concentrations may alter the hematological response to reduced gas exchange on gill lamellae (Sherk et al. 1974). Impedance of water flow may secondarily effect excretion and salt balance when gill lamellae become covered with sediment particles (Cordone and Kelley 1961). Stern and Stickle (1978) indicate that juvenile fish may be more sensitive to suspended solids due to their higher ratio of gill surface area to body size and elevated metabolic rate. Wilber (1971) states that fish that are visual feeders may be less successful in response to reduced light penetration. Cisco over-winter in the St. Marys and are numerically abundant throughout the system. Reduced feeding success may affect growth and, secondarily, fecundity. Yellow perch and pike may also be affected to a lesser extent.

Ice breaking and vessel passage through the river also could extend the depth of the ice pack in areas immediately adjacent to the navigation channel by pushing flow ice under the off-channel ice pack (Keith Kraai, personal communication). In shallow near-channel habitats of the river fish movement patterns may be altered or suspended. Winter data from gill net catches indicate fish movement to be higher in the near channel area. Burbot appear to travel both the ship channel and near channel area (personal observation and conversations with sport fishermen). Cisco move along the ship channel margin during winter. Movement patterns and rates for these species may be altered by winter shipping. The majority of northern pike, perch and cisco captured during winter were females, indicating greater movement for female fish in winter, possibly as a response to higher feeding rates. Off-channel vessel-created ice obstructions may block or obstruct fish movement, limiting foraging areas available and possibly increasing energy expenditures. Increased metabolic cost by increasing search time may be reflected in lowered fecundity and/or growth rates.

Alteration of fish movement patterns during both winter and open water periods in the Middle Neebish Channel due to habitat alteration and off-channel ice obstructions is likely to occur. Immediate effects on juvenile and adult fishes do not appear substantial. However, disruption or abandonment of spawning and/or foraging grounds, altered diel and seasonal movement patterns, and affects on specific stocks of fish utilizing areas adjacent to

the navigation channel may not manifest themselves for some time. Current sampling techniques should be replicated in areas subjected to winter ship traffic to determine and verify any changes in fish abundance, movement, and indicators of stock composition and condition (sex ratio, age structure, food habits, growth rates, and fecundity of spring spawning fish).

Small Mesh Trap Nets

The upper littoral zone of the St. Marys River supports an extensive and diverse fish community. A wide size and age range of fishes were found in this zone, although most individuals were juveniles. The shallow water of the upper littoral zone is a nursery area for several important sport and forage fishes. The importance of the littoral zone to fish larvae in the St. Marys River has been previously reported (Liston et al. 1981).

Sport fishes that utilize this zone as a nursery area include: black crappie, bluegill, brown bullhead, largemouth bass, northern pike, pumpkinseed, rock bass, smallmouth bass, white sucker and yellow perch. The emergent vegetation is important to these juvenile fishes. Aquatic macrophytes are a major component of primary production in the St. Marys River (Liston et al. 1980) and overall productivity is enhanced by invertebrate colonization of the attachment sites and grazing surfaces provided by the plants (Swanson et al. 1979; Gerrish and Bristow 1979; Keast 1968). This results in large invertebrate populations available as food for the juvenile fish. The emergent vegetation also provides cover. Macrophytes are reported to provide cover for both predator and prey (Gerrish and Bristow 1979; Werner et al. 1978). As the juvenile sport fish attain larger sizes (75 - 125 mm) they generally move offshore. However, brown bullhead, northern pike, rock bass, and white sucker adults regularly use the upper littoral zone as a feeding area.

The most abundant forage fishes found in the upper littoral zone included the bluntnose minnow, common shiner, golden shiner, mimic shiner, sand shiner, and spottail shiner. Younger (<100 mm) cyprinids are generally found in shallower waters than older individuals (Moyle 1973). Mature cyprinids were also commonly found in the upper littoral zone suggesting the importance of this habitat to all age groups.

Considerable annual variation in species abundance was apparent. This variability was largely a result of changes in year class strength. Year class failure of a particular species may or may not be related to the effects of commercial navigation. If, however, populations of certain species are consistently larger in comparable areas not exposed to the effects of commercial navigation (Lake George), then populations in the navigated areas are being impacted. Populations of several sport fish appeared to be numerically larger in Lake George than Navigation Course 5 during 1981. These species included yellow perch, smallmouth bass, largemouth bass, northern pike and white sucker. Brown bullhead and bluegill populations appeared to be greater in Navigation Course 5 than Lake George during 1981. Average Lake George collections (CPE = 326.9) were much larger than Navigation Course 5 collections (CPE = 68.7) due to the abundance of both sport and forage fish in Lake George.

The effects of the proposed extension of the shipping season on the fish community of the upper littoral zone are speculative. Turbulence under ice cover from passing vessels may directly injure fish or disrupt normal behavior. Normal behavior may also be affected by increases in turbidity. Activity of the largemouth bass has been reported to be substantially reduced by increases in turbidity (Heimstra et al. 1969). Green sunfish activity was also reduced slightly and evidence suggests that normal social hierarchies were disturbed by increased turbidities (Heimstra et al. 1969). Feeding behavior may also be influenced by increases in turbidity. Turbidity significantly reduced feeding rates but not size selectivity of bluegills (Gardner 1981). It has also been suggested that mobile zooplankton may be favored by higher turbidities because they can rapidly move out of sight of predators (Gardner 1981). Exposure to adverse conditions for short time periods may be tolerated by some species better than others and the effects of chronic exposure are uncertain (Stern and Stickle 1978). Ice scouring of over-wintering root systems of emergent macrophytes during periods of season extension could reduce available habitat for many species found in the upper littoral zone. Many fish species prefer areas containing certain vegetation types and/or densities (Moyle 1973; McCarraher 1972; McCann 1959). The impact of these possible effects will vary with different species. Therefore, the impact of the proposed season extension and pertinent biological information of numerically and ecologically important species are discussed below.

Bluegill. The upper littoral zone of the St. Marys River is a nursery area for bluegill. Very few (<2%) bluegill older than young-of-the-year were taken by any gear, suggesting predation and/or emigration. Bluegill were not found in stomachs from northern pike, walleye, and yellow perch (Liston et al. 1981). However, the predatory fish examined may not have been taken from the extremely shallow areas frequented by the young bluegill. In another study, heavy utilization of small bluegills by yellow perch during the winter reduced the bluegill population significantly (Moffett and Hunt 1943). Older bluegill may also move away from the shipping channel into low current areas. Adults are generally found in heavily vegetated slowly flowing areas of rivers due to their body shape and feeding behavior (Scott and Crossman 1973; Keast and Webb 1966).

Bluegill collections in the small mesh trap nets were greater in 1980 than 1981 indicating year class variation. Abundance of young-of-the-year bluegills has been reported to vary considerably from year to year (Mayhew 1956). A poor 1981 year class in Lake George was probably responsible for the relatively low catches there.

Bluegills are generalized feeders but rely primarily on cladocerans and ephemeropterans during the winter. The amount of food consumed by bluegills during winter is small compared to summer. This reduction in food intake has been attributed to a lower metabolic rate during winter (Moffett and Hunt 1943). During the winter, bluegill may congregate in deeper water than during the summer (Scott and Crossman 1973).

Bluegills favor vegetated areas and consequently, reduction of macrophytes could reduce optimal bluegill habitat. Possible increases in suspended solids in the water column due to vessel passage may interfere with the lower winter

food intake of bluegills. Turbidity, caused by clay particles, has significantly reduced feeding rates but not size selectivity of bluegills (Gardner 1981). A lowered food intake during a period of increased stress could affect both survival and growth of bluegills.

Yellow Perch. The upper littoral zone of the St. Marys River is extensively utilized by young-of-the-year and age I yellow perch. Although young yellow perch are generally found in shallower water than older fish, larger individuals were also found in the upper littoral zone. Age I yellow perch apparently move out of the littoral zone to deeper water in late summer. Although yellow perch were taken throughout the river they were most abundant in Navigation Course 7 and Lake George.

Yellow perch are diurnal (Keast and Welsh 1968) and consequently catches in the small mesh trap nets during the day were larger than collections at night. Collections varied considerably from 1980 to 1981. Catches were greater at Navigation Courses 7 and 9 but were lower at Navigation Course 5 in 1981.

During the winter, large juvenile and adult yellow perch were found mainly in shallow water where they fed on insect larvae (Liston et al. 1981). Young-of-the-year apparently over winter in very shallow water and continue to feed on zooplankton and other small invertebrates (Hansen and Wahl 1981; Keast 1968). Turbulence from passing vessels during this period may affect yellow perch growth and survival. Growth rates of young-of-the-year yellow perch have been found to be negatively correlated with turbidity values (El-Zarka 1959). Yellow perch populations in a body of water have also been reported to decrease when turbidity values increased (Scott and Crossman 1973).

Reduction of vegetation in a body of water has also been linked to reductions in yellow perch populations (Scott and Crossman 1973). Possible scouring by ice of the upper littoral zone during the proposed season extension may reduce the emergent vegetation of the St. Marys River.

Yellow perch are a key component in percid communities found in northern boreal lakes (Ryder and Kerr 1978). In addition to being an important sport fish, they also provide forage for walleye (Kelso and Ward 1977). Any reduction of yellow perch populations on the St. Marys River may also impact walleye populations.

Northern Pike. Northern pike were commonly taken in the upper littoral zone by the small mesh trap nets. Several age groups of pike were present and these fish were apparently feeding on the forage fish found in the emergent vegetation.

Northern pike were more abundant in the upper littoral zone of Lake George than the other areas. During the periods of the proposed season extension northern pike would be active and feeding. Winter food intake of northern pike is, however, lower than food intake at other times of the year (Diana and Mackey 1979; Keast 1968). This species consumes enough food that it may effect the populations of other vertebrates in its habitat (Scott and Crossman 1973). This important sport fish could be adversely impacted if populations of forage fishes

in the upper littoral zone are reduced. Reduction of certain types of vegetation in the upper littoral zone may affect northern pike spawning success. Northern pike are reported to prefer certain species of macrophytes for spawning (McCarraher 1972).

Brown Bullhead. Brown bullheads extensively use the upper littoral zone of the St. Marys River. Brown bullheads appeared to be more abundant in Navigation Courses 5, 7 and 9 during 1981 than 1980. A strong 1981 year class may account for this increase but bullheads of all sizes use the upper littoral zone. Brown bullheads were taken in greatest numbers during the spring and fall. Winter brown bullhead behavior is unknown but they are characterized as moderate winter feeders. During the winter they rely primarily on cladocerans, amphipods, ostracods, chironomids and fish (Keast 1968). Bullheads are nocturnal and use their chemotactile barbels to locate food (Keast and Welsh 1968; Keast and Webb 1966). This behavior explains the large night collections in the small mesh trap nets and small collections during the day.

Brown bullhead are considered an environmentally tolerant species (Scott and Crossman 1973). They do not appear to have been dramatically affected by commercial navigation and are currently more abundant at one navigated area (Navigation Course 5) than the non-navigated area (Lake George). Reduction of emergent vegetation would expose young to predation but increases in suspended solids could favor this species.

White Sucker. The upper littoral zone of the St. Marys River is a nursery area for white suckers. White suckers were collected in greatest numbers by the trap nets in Navigation Course 7 but they were abundant throughout the St. Marys River. White suckers were taken in greatest numbers in the upper littoral zone during the summer and fall due to recruitment of young-of-the-year. Age I white suckers were also found in the upper littoral zone during the spring indicating that at least some of the juvenile white suckers remain in shallow areas during the winter. Although most were young-of-the-year and age I fish, older white suckers were also collected. Mature white suckers are reported to frequent shallow water in addition to deeper areas (Kavaliers 1980). The adult fish are probably feeding on the benthic invertebrates found in the littoral zone. Juvenile white suckers also feed on the benthic invertebrates of the littoral zone and may utilize the emergent vegetation for cover to avoid predation. Young-of-the-year white suckers are largely restricted to the littoral zone while some older juvenile suckers move to deeper waters where they have been collected in the trawls (Liston et al. 1981).

White suckers may fill an important role in energy transfer between trophic levels in the St. Marys River (Liston et al. 1981). White suckers feed predominately on small benthic invertebrates such as amphipods, chironomids and zooplankton (Koehler 1979). They also may constitute a large portion of the diet of northern pike, muskellunge, basses, walleye and burbot (Scott and Crossman 1973).

In addition to providing forage for large predatory sport fish, white suckers also provide a recreational fishery during their annual spawning run into the tributaries of the St. Marys River. The white sucker is, however,

generally considered a species that is underutilized by sport and commercial fisheries (Galloway and Kevern 1976).

Extension of the commercial navigation season could affect white suckers in two ways. Reduction of emergent macrophyte beds would reduce available cover and foraging habitat for adults and juveniles. Young-of-the-year and age I white suckers apparently are present in the upper littoral zone during the extension periods and turbulence under ice cover from passing vessels could affect survival and habitat utilization.

Spottail Shiner. Spottail shiner is a common Great Lakes species that is very abundant in the upper littoral zone of the St. Marys River. This species is generally found in greatest numbers in areas of moderate amounts of submergent vegetation (McCann 1959). In certain areas of the Great Lakes, the spottail shiner may have ecologically replaced the emerald shiner (Wells and McLain 1973). In the St. Marys River, this species was taken throughout the littoral zone by trap nets and trawls.

This species was collected in greatest numbers during the summer in both the navigated and non-navigated sampling areas. Spottail shiners were taken in considerably greater numbers in Lake George than Navigation Courses 5, 7 and 9. If current commercial navigation has impacted spottail shiner populations the mechanism is unknown. The greater Lake George collections appeared to be due to a large year class that was not present to the same degree in the other sampling areas. Although most individuals were young-of-the-year or age I, older fish were also commonly taken.

The winter habits of the spottail shiner are poorly described and consequently the impacts of the proposed season extension are speculative. This species prefers vegetated areas and reductions in those areas would have an impact. This species is also considered an important component of the walleye food chain in some areas (Smith and Kramer 1964) and the walleye is an important sport fish in the St. Marys River.

Common Shiner. The common shiner was very abundant in the upper littoral zone of Lake George. This species was also taken in the navigated sampling areas, but in lesser numbers. Most common shiners were young-of-the-year. Young common shiners are reported to frequent extremely shallow waters while older individuals prefer waters 1 to 4 meters deep (Moyle 1973).

This species is considered an opportunist and may take advantage of an unexploited food supply following the year class failure of other cyprinids (Moyle 1973; Starrett 1950). Although this could explain the relatively large population of common shiners in Lake George, it is also possible that common shiners are being impacted by commercial navigation. If the latter is true, the mechanism is unknown at the present time. This species was most abundant during the summer. Winter habits are poorly described. Any impact on submerged macrophytes could be important to this species because adult common shiners are reported to select certain macrophytes (*Chara* sp.) to school over (Moyle 1973).

Bluntnose Minnow. Bluntnose minnows were abundant in both the non-navigated area (Lake George) and Navigation Courses 7 and 9. The large day collections and the small collections taken during the night are due to this minnow's behavior. Bluntnose minnows are inactive at night resting on the bottom while during the day they are active plant and bottom feeders (Moyle 1973).

The large summer catches could be due to greater activity during periods of warm water temperatures or, bluntnose minnows may move to slightly deeper water when water temperatures cool. Bluntnose minnows are generally found in water from 1 to 4 meters in depth and the small mesh trap nets were not sampled deeper than 1.5 meters. During the winter bluntnose minnows are reported to remain close to the bottom and feed largely on algae (Moyle 1973).

Bluntnose minnows were more abundant in 1981 than during 1980 in Navigation Courses 7 and 9. A strong year class might account for these differences. Other research (Moyle 1973) indicates that the lengths of bluntnose minnows represented in the small mesh trap nets would correspond to ages 0 - III. Although bluntnose minnows use both vegetated and open areas, the majority of the population is generally scattered in small schools throughout the macrophyte region (Moyle 1973). These minnows are considered a forage species for yellow perch and centrarchids (Scott and Crossman 1973).

Bluntnose minnows may remain in the shallow water areas adjacent to the shipping channels during the periods of the proposed season extension. Turbulence could affect winter survival and ability of this minnow to feed. Alteration of macrophyte beds would also reduce the preferred habitat for this species.

Many other species were commonly found in the upper littoral zone of the St. Marys River. Juvenile black crappie, largemouth bass, pumpkinseed, rock bass and smallmouth bass are sport fish that also utilize the upper littoral zone as a nursery area. Several other forage species were also taken suggesting habitat complexity. Any degradation of this zone by winter shipping activities would also likely impact on these species.

Trawls

The following discussion concerns the biology of those species of importance in the trawl samples that were not adequately sampled with other gears. A possible stress imposed on these populations by winter navigation could be disruption of spawning habitat, and each species is susceptible to such stress in varying degrees. The species sampled by the trawl are all spring or summer spawners, thus there is no danger of actual egg destruction by winter shipping but rather the problem lies in the possible disruption of submergent and emergent macrophyte beds which are the spawning sites for certain species. Also, increased sedimentation may cause added mortalities to eggs or larvae.

Johnny darters tend to inhabit areas of sand and gravel bottom, and are known to spawn on the underside of rocks or other structures (Winn 1958). Therefore they are not likely to be directly affected by loss of plant beds. Johnny darters do provide some forage for such species as burbot, smallmouth bass and walleye (Scott and Crossman 1973).

Ninespine sticklebacks spawn strictly in aquatic plant beds, building and guarding a nest. Populations of sticklebacks could, then, be reduced by loss of macrophyte beds. They are important items in the diet of walleye, yellow perch and burbot (Dymond 1926; Rawson 1957) and thus a decline in ninespine numbers could lead to a reduction in growth or numbers of some important game species present in the St. Marys.

Trout-perch spawning habits are not well known but they have been observed entering shallow rocky streams in north-central Manitoba (Lawler 1954) and spawning over a sand and gravel bottom in Red Lake, Minnesota (Magnuson and Smith 1963). Spawning was not associated with macrophyte beds. Trout-perch were found to be important in the diet of northern pike (Lawler 1954) and of walleye (Magnuson and Smith 1963) so that any change in the population could have an impact on economically important species.

Yellow perch spawning is almost always near rooted vegetation. Eggs are scattered but adhere to vegetation or at times to the bottom, and loss of vegetation may be detrimental to the perch population. Yellow perch have been observed in stomachs of various centrarchids including largemouth and smallmouth bass, walleye, sauger, other yellow perch, northern pike and muskellunge (Scott and Crossman 1973), and thus provide a very important forage base.

Spottail shiners are also important prey for many species of economic importance. Spawning takes place in spring and early summer over sandy shoals, however, so that loss of aquatic plants is not likely to have a direct impact on spawning success.

Both the mottled sculpin and slimy sculpin spawn under rocky overhangs or other structures during spring (Ricker 1934; Koster 1936; Bailey 1952; Savage 1963). Like the johnny darters they tend to inhabit open areas of sand and gravel. Again, loss of macrophyte beds is not likely to have direct impact on these species. Sculpins do provide forage for games species and have been observed in stomachs of pike and burbot.

Mimic shiners spawn in early summer. Black (1945) speculated that spawning takes place over aquatic vegetation at depths of 15 to 20 feet but accurate observations are not available, and the importance of vegetation to spawning success is unknown. Black (1945) also observed that the primary predators on the mimic shiner population in Shiner Lake, Indiana were largemouth and smallmouth bass. Mimic shiners are quite probably prey to other game species in the St. Marys River such as northern pike, walleye and yellow perch.

Logperch have been observed to spawn in early summer over sandy shoals, where the eggs were buried in sand (Winn 1958). Aquatic vegetation was not of direct importance to spawning success. Game species known to prey on logperch include walleye (Raney and Lochner 1942) and northern pike (Greeley 1927).

Spawning success of rainbow smelt should not be substantially affected by winter navigation as this species spawns in spring, primarily in tributaries to the St. Marys River, although some activity may occur in the river proper. Smelt are quite important economically as they are an important game species

and in addition provide substantial forage for other game species. Any significant stress to the smelt population could have considerable effect on the St. Marys fisheries as a whole.

In summary, three of the major species captured by trawl, ninespine stickleback, yellow perch and mimic shiners, may be directly affected by reduction of macrophyte beds. All species could be affected by increased deposition of sediment on spawning substrates if such should occur. All species are important directly as game fish or indirectly to some degree as a forage base for game fish. Disruption of macrophyte beds and increased sedimentation, both possible effects of winter navigation, could lead to reduction in fish populations, but any discussion of such losses should be tempered with considerations of compensation by the populations in question. Decreased reproduction may lead to increased survival of fry of successful spawners. Also to be considered is the importance of the diverse habitat available in the St. Marys River system. Reduction of fish production from one area may be off-set by immigration from other sites, provided that sufficient fish habitat remains unaffected by winter navigation activities.

Impacts from winter navigation on the fish communities sampled by trawls is speculative at this stage. General effects from shipping appear to result in a somewhat less diversified and less abundant fish community, as indicated from shipping vs. non-shipping channel comparisons made in this report. Additional shipping and further physical disturbance of the St. Marys River may be expected to negatively impact fish communities, but the degree and significance of the impact remains conjectural. Quantitative measures of fish abundance (catch per standardized effort) and measure of species specific biological parameters (i.e. age and length composition, food habits) now established under baseline conditions require extended, replicated, study in the face of future winter shipping to discern the significance of any impacts.

PHYSICAL AND CHEMICAL ASPECTS

Water Chemistry, Temperature and Turbidity

Water Temperature. The importance of water temperature to aquatic organisms is well documented, and several authors have compiled extensive bibliographies on temperature and aquatic organism relationships (Raney and Menzel 1969; Beltz et al. 1974). Classification of aquatic systems with typical assemblages of flora and fauna may be based upon water temperature regimen.

Water temperatures along the shoreline were warmer than offshore waters in spring and summer but cooler than offshore waters in fall. Offshore temperatures in the St. Marys River are influenced primarily by Lake Superior (Liston et al. 1980) whereas the nearshore (shallower) water temperatures appear to be controlled by climatic conditions (Liston et al. 1981). This nearshore-offshore temperature stratification regimen probably plays an important role in the seasonal distributions of aquatic flora and fanua in the St. Marys River.

Maximum water temperatures were recorded during August through early September. The higher maximum temperatures occurring later in the season in Lake George, compared to the other sites, is probably due to the extensive shallow area along the southern portion of Lake George producing water temperatures which were more susceptible to climatic conditions.

Dissolved Oxygen. Dissolved oxygen measurements generally remained at high levels with the lowest values occurring during summer in the nearshore areas. These lower values may be attributed to the higher water temperatures during summer as well as samples being taken at night, during fish sampling, when lower dissolved oxygen levels may be expected due to respiration. Oxygen levels were generally similar to those reported from Lake Nicolet by Kenaga (1979).

Turbidity. Presentation of turbidity results have been confusing in the past and to date are often misunderstood. To quote APHA (1971) "turbidity should be clearly understood to be an expression of the optical property of a sample which causes light to be scattered and absorbed rather than transmitted in a straight line". The 14th edition of Standard Methods adopted the Nephelometric turbidity unit as a standard expression (Hach 1974). Turbidity is often erroneously expressed as ppm. Accordingly, turbidity values reported are in NTU's.

Increased turbidities in the different areas and seasons are related to depth and wind action. The higher fall turbidities no doubt are a result of the strong winds characterizing this time. Ice cover in winter disallows wind induced turbulence such that winter turbidity is influenced mostly by Lake Superior. Nearshore areas, being shallow, are susceptible to wind-induced waves that resuspend sediments. The extensive shallow area in Lake George allowed a large area to be affected by wind creating higher turbidites than in the other sites.

Dissolved Solids. The relatively low dissolved solids content at all sites were similar to previous dissolved solids measurements reported for the St. Marys River (Kenaga 1979; Liston et al. 1980). The comparable magnitude and invariability of St. Marys River dissolved solids content to that of Lake Superior (Kinkead and Chatterjee 1974) demonstrates the dependence of this parameter on Lake Superior.

pH. The pH of water is a measure of the hydrogen ion concentration, and may be influenced by O_2 levels, CO_2, minerals, and sediment character (Hutchinson 1957). The pH values in the St. Marys River recorded during 1981 had a greater range (4.9 to 9.2 S.U.) than previously described by Liston et al. 1981. The pH values were generally within the range described for natural waters (Wetzel 1975). The increasing variability in pH values as the seasons progressed may be attributed to diurnal fluctuations in photosynthetic and respiratory activities by plants (Wetzel 1975). The pH samples, taken at different times of day and night, would be expected to be influenced by plant metabolic activities.

Sediment Chemistry of Shipping and Non-Shipping Channels

Results indicate the sediments of Lake Nicolet are more polluted than those of Lake George. Of the contaminants present in consistently detectable amounts, all except H, and oil and grease occurred in greater average amounts in the shipping channel (Lake Nicolet) than the non-shipping channel (Lake George). Twelve of the 17 instances where a parameter exceeded moderate pollution criteria occurred in Lake Nicolet. Additionally, total volatile solids, COD, Zn and Fe levels, while not exceeding moderate or heavy pollution criteria, were present in substantially higher levels in Lake Nicolet. TKN, NH_3-N, and Arochlor 1260 (PCB) were nominally higher there (Table 43).

The same six parameters (P, As, Cu, total Cr, Ni, Mn) exceeded moderate or heavy pollution criteria at both sites, while those parameters considered non-polluted were so at both sites, and those below the level of detection were undetectable at both sites. This consistency in appearance of contaminants suggests both sites receive similar pollutant loadings; apparently shipping activity does not introduce additional substances into the sediments of Lake Nicolet.

The consistent appearance of pollutants could suggest shipping may affect both sites via inputs to the main river above the divergence of the channels. If this were so, uniform contaminant levels would be expected up and down the shipping channel. This possibility is largely disproven since all parameters except Ni and TKN are lower in the shipping channel above Sault Ste. Marie than in either Lake Nicolet or Lake George (Kenaga 1978; Dames and Moore 1978; Hamdy et al. 1978).

This does not imply shipping has no impact upon the river sediments. Instead, shipping effects may manifest themselves through alteration of the dynamics of the sediment and its constituents. The most obvious hydrodynamic effect of a freighter's passage is drawdown. The displacement of a moving ship induces flows that cause the water level to fall up to 60 cm for about one minute (personal observation). For perspective, these flows may possess sufficient force to displace benthic macroinvertebrates (Gleason et al. 1979). This action may re-suspend sediments and carry them further downstream, the net effect being removal of sediments from one area and introduction of them to another area. Sediment samples from the sites in Lake Nicolet may represent a "slug" of polluted sediments moving through, while such a "slug" in Lake George may have passed or not yet have arrived. However, this transport of sediments may also be due to the greater ambient current speeds in Lake Nicolet (Table 46) and not drawdown currents.

Contaminant levels at the two sites may differ due to factors other than shipping. Ambient currents are slower and water must travel farther before it reaches the sampling site in Lake George, so pollutants may fall out prior to reaching those sampling sites. This concurs with the results of Hamdy et al. (1978), who reported higher contaminant levels in the embayments upstream of Lake George than in the Lake George channel.

Sedimentation rates in the winter of 1980-81 were greater in Lake George versus Lake Nicolet (Fleischer 1981). Industrial discharge of pollutants has

Table 46. Current speeds at sediment sampling sites in the St. Marys River[1].

		Speed (cm/s)	
		Surface	Bottom
Lake George (non-shipping)	West	8.8	6.7
	Channel	34.2	28.8
	East	16.1	14.2
Lake Nicolet (shipping)	West	15.2	15.2
	Channel	39.7	28.8
	East	20.3	-

[1]Current speeds measured with a Gurley current meter on 24 July and 7 August, 1981.

decreased steadily since 1974 (Ontario Ministry of the Environment 1981). These conditions may result in new, cleaner sediments burying older, more contaminated ones faster in Lake George than in Lake Nicolet. This may give the less polluted values in Lake George.

It is likely that the two channels receive different loadings for various parameters. The only large industries in the area are Algoma Steel and Abitibi Paper companies in Sault Ste. Marie, Ontario, and while their main trunk sewer is located upstream of the channels' divergence, complete mixing of the effluent with river water does not occur. Hamdy et al. (1978) have shown that Zn, Fe, CN, and phenols are much higher along the Canadian shore, with only small amounts of trans-boundary movement occurring. This may cause high levels for some parameters in Lake George. However, about 71% of the total flow of the St. Marys River is directed down Lake Nicolet (Bell 1981). Therefore, while contaminant concentrations may be lower on the American side, a significant quantity may still be transported down Lake Nicolet due to the greater flows there.

It would be expected that Lake Nicolet would have coarser sediments due to the removal of the finer particles by stronger ambient currents and drawdown currents, but this is not the case. Apparently the geology of the two sites determines the sediments present, for while Lake Nicolet has much finer sediment particles, they are comprised of very cohesive clays, and thus are not eroded away very swiftly. Lake George, while not having strong currents does have deposits of coarse sands and coarser sediments. This situation has important implications on the chemistry of each site.

The processes by which heavy metals, nutrients, and other constituents transfer across the sediment-water interface are complex and not fully understood. Clay content, organic fraction, redox potential, sediment pH, bacteria present and the sulfur and iron cycles are thought to play important roles in these processes (Morton 1977). Allen (1976) states that metals may combine with various organic compounds found in natural waters. COD and total volatile solids provide approximations of the total organic carbon present in a sample (APHA 1976), and both these parameters were substantially higher in Lake Nicolet. Furthermore, clays are known to preferentially adsorb heavy metal ions (Morton 1977), and the sediments in Lake Nicolet tended to be finer and contain more clays, especially when compared to the Lake George channel sample. This combination of a higher clay and organic matter content at Lake Nicolet implies the sediments there may attract and retain metals and other pollutants better than the sediments in Lake George. Additionally, organic compounds frequently contain nitrogen and phosphorus, which may account for the higher levels of TKN, NH_3-N and total P in Lake Nicolet.

Besides differences in contaminant levels between the two lakes, a similar trend occurred within each lake with the east of channel sites being non-polluted and the west of channel sites having the polluted values (Tables 43 and 44). Lake George had coarser sediments on the east side, and total volatile solids (hence organic matter) were lower there, so metals may not adsorb to those sediments as readily. COD, also an indicator of organic matter, is in disagreement with this conclusion. Lake Nicolet sediments

were nearly the same size at both the east and west sites, and COD and total volatile solids values were nearly equal as well, leaving no apparent explanation for the differences in that case.

If winds in the region are assumed to be predominantly westerly in direction (as in the rest of the U.S.), the eastern shores of the lakes would receive more wave action than the western shores, possibly causing the re-suspension and removal of sediments from the eastern shores. The coarser sediments in eastern Lake George support this idea, but the Lake Nicolet sediments do not.

As was mentioned earlier, the clays, organic compounds, redox potential, sediment pH, bacteria and sulfur and iron cycles are important factors in the release of contaminants from sediments. These were not evaluated in this study. Lee and Plumb (1974) emphasize that bulk analysis of sediments cannot predict the movements of pollutants to or from the water column, and recommend the elutriate test as a better indicator.

While definite trends occurred in the data of this study, several inconsistencies also appeared, demonstrating the need for more numerous samples. Phenol inputs to the river have been documented (Ontario Ministry of the Environment 1981; Hamdy et al. 1978), and should be investigated further. In view of this, a more thorough analysis and a greater number of uniform samples are required to better explain the condition of the St. Marys River sediments.

SUMMARY

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrate sampling in the St. Marys River during 1981 was aimed at two objectives. The first objective was to determine the extent of annual variation exhibited by the benthos at a specific site. To accomplish this, sampling methods employed in 1979 were replicated at Navigation Courses 7 and 9 during 1981 including sampling apparatus (PONAR grab), replication (60 samples), and time of sampling (June and September).

The second objective of the benthos program was to compare the fauna inhabiting a portion of the river presently used for navigation with a similar environment not presently used for commercial navigation. Sampling to satisfy this objective was conducted bimonthly from April through December in Lake George and Navigation Course 5 (Lake Nicolet). On each of five sampling dates triplicate PONAR grab samples were collected from the three meter depth zone while triplicate Ekman grab and Gerking samples were collected from within the vegetated littoral zone of each area. Thus, 9 samples were collected per area per date or 90 total samples. In addition, a portion of the 1981 data from Course 5 could be compared with 1979 data. Other sampling during 1981 consisted of six PONAR grab samples from within the navigation channel of Course 5 during winter.

Estimates of total benthic macroinvertebrate abundance within Navigation Courses 7 and 9 ranged from $2,016/m^2$ to $22,340/m^2$ outside the navigation channel. Within the navigation channel abundance of total benthos was significantly less and ranged from 980 to $4,186/m^2$. Chironomidae larvae were the predominant taxa encountered in samples comprising 55.5 - 59.9% of the total benthos. In all, 87 taxa were identified in samples from these two navigation courses. In addition to Chironomidae, the following taxa were considered common: Oligochaeta, Ephemeroptera, Amphipoda, Isopoda, and Trichoptera.

Abundance of total benthos was greater at all sites in 1981 than 1979. At Navigation Course 7 abundances found in June and September 1981 were 132% and 122% those recorded during the same period in 1979. At Navigation Course 9 total benthos abundance during June 1981 was 235% that found in June 1979. Abundance of total benthos at Course 9 was almost equal during both years in September. Greatest increases in total benthos during 1981 were found at Course 5. However, because of limited replication these data are considered less reliable than data from Courses 7 and 9.

Changes in the taxonomic composition of the benthos at Courses 5, 7 and 9 from 1979 to 1981 occurred, but were restricted to genera of Chironomidae. These shifts in the generic composition of the Chironomidae likely reflect natural annual variations in timing of pupation and emergence of chironomids as predominant genera collected during both years have similar water quality requirements.

Seasonal average abundance of total benthos at the three meter depth of Course 5 ($13,771/m^2$) was greater than that found in Lake George ($9,084/m^2$). Within the vegetated littoral zone seasonal averages of total benthos were similar in Course 5 ($18,506/m^2$) and Lake George ($17,915/m^2$). While statistically significant, differences between these sites exhibited no consistent pattern.

Both Course 5 and Lake George support similar benthic fauna. Eight-two taxa were found in Course 5 and seventy-five taxa in Lake George; of these fifty-nine taxa were common to both sites. Although all common taxa were present in both areas, they comprised different proportions of the total benthos. In Course 5 Chironomidae comprised 55.4% and 57.3% of the benthos at the three meter depth and in the littoral zone, respectively. The second most abundant taxon in Course 5 were Oligochaeta. In Lake George Chironomidae were also abundant comprising 46.1% of the total benthos at the three meter depth and 44.6% in the vegetated littoral zone. However, the second most abundant taxon was Ephemeroptera. In addition, mollusks (pelecypods and gastropods) were more common in Lake George than Course 5. Because organisms common in Lake George attain greater size than organisms common in Course 5 standing stock in Lake George was greater than in Course 5. Seasonal average standing crops in Lake George were 17,183 mg/m^2 and 6,688 mg/m^2 at the three meter depth and in the littoral zone, respectively. In Course 5 seasonal average standing stock at the three meter depth was 6,386 mg/m^2 and in the littoral zone was 4,550 mg/m^2.

Estimates of benthic secondary production for 15 common taxa were similar among Course 5 and Lake George when both habitats were considered. Benthic secondary production at Course 5 was 10,704 $mg/m^2/yr$ at the three meter depth, and 11,318 $mg/m^2/yr$ within the littoral zone. In Lake George secondary production at the three meter depth and in the littoral zone was 16,046 and 6,171 $mg/m^2/yr$, respectively. Estimates of annual rates of production of benthos are important measures of the potential for fish food production in various aquatic habitats. Comparisons of benthic productivity between navigated and un-navigated portions of the St. Marys were done to observe possible changes in production attributable to navigation in general.

AQUATIC MACROPHYTES

During 1981, studies were conducted to improve baseline information on distribution and abundance of aquatic vegetation in the St. Marys River. The distribution of aquatic plants along transects adjacent to Navigation Course 5 in Lake Nicolet and Navigation Course 7 of the Upbound Neebish Channel, and in Lake George, an un-navigated habitat, was mapped. Dominant emergent species were *Scirpus acutus* (hard stem bulrush) and *Scirpus americanus* (three square

bulrush). The time of year when stands of these reached maximum biomass appeared temperature dependent. Shoots germinated from rhizomes in April - May when water temperatures reached 5 - 7°C, and required on the order of one degree day per centimeter of water depth to emerge into the atmosphere. On a site protected from circulation of cold channel water into the warmer shore zone, maximum biomass was present from 15 July into September. On a site exposed to circulation of cold channel water, maximum biomass was not present until after 20 August. At maturity, in the most well developed portions of their beds, S. acutus and S. americanus biomass was 540 and 272 g ash-free dry weight m^{-2}, respectively. The charophytes (Nitella flexilis and Chara globularis), and Isoetes riparia (quillwort) dominated submersed vegetation on transects. Beds of these plants tended toward nearly constant growing season biomass. Dead or dying tissue of the previous growing season appeared to be sloughed at a rate approximately equal to the rate of replacement of biomass by new growth. In August - September, beds of these plants consisted of new growth. Biomass at that time was 50 - 70 g ash-free dry weight m^{-2}. Differences between transects in Lake Nicolet and Lake George in regard to species, their distributions, and biomass could not be documented by this study. However, the water of Lake George was warmer and thus provided a contrast for evaluating temperature control on growth and development of maximum annual biomass.

Hand sampling techniques were developed for obtaining biomass in submersed plant beds. Thirty samples were taken from beds of Nitella flexilis and Isoetes riparia by hand and by PONAR dredge. A standard procedure was established for converting data obtained by PONAR dredge to hand-sampled equivalents.

Beds of submersed plants found at the edge of the Upbound Neebish Channel in 1979 were sampled randomly with the procedures of 1979. Beds occurred in the same locations in 1981. The same species dominated beds in both years and biomass within beds was similar in these years.

Impacts from an extended shipping season (to January 31 ± 2 weeks by 1987) on aquatic plants are expected to result mainly from scouring over-wintering rootstock systems by ice movement and under-ice pressure waves created by passing ships in narrow channel passages. The degree of quantitative change is unknown and could only be determined through careful measurement. Studies being carried out in 1982 and 1983 are documenting the existing extent and substrate biomass of rootstock systems of emergent plants at numerous sites along the River. Further, precise mapping of beds of emergent plants through modern aerial photography is producing extensive pre-project baseline data on stands of emergent macrophytes.

ICHTHYOPLANKTON

In 1981, the ichthyoplankton sampling program was designed to estimate species composition and relative abundance of larval fish in Navigation Courses (Stations) 5, 7 and 9 and Lake George in the St. Marys River. The collections in Course 5 (Lake Nicolet) and Lake George were designed to detect differences in the ichthyoplankton in a navigated and a non-navigated area. Collections

in Courses 5, 7 and 9 helped determine annual changes in larval composition and relative abundance. Larval fish were collected using metered 351 μ mesh plankton nets in three habitats: the shallow littoral zone (<0.5 m); along the edge of macrophyte beds (1 - 2 m); and, the deeper open water channel areas.

Biweekly samples from April through September yielded 8,599 larvae in a total of 378 samples. Larvae of 20 taxa were collected with the majority (57.1%) of the total catch comprised of rainbow smelt, Sucker, cyprinid and burbot larvae were the next most abundant individual taxa, comprising 6.9, 10.3 and 5.1% of the total catch, respectively. As a group, percids (yellow perch, logperch, johnny darter, and unidentified darters) comprised 13.8% of the total catch. Inshore catches were dominated by cyprinids, suckers and percids, while offshore collections were dominated by rainbow smelt larvae.

Seasonal trends of appearance and abundances of larvae were apparent and followed those of 1979 and 1980 and are typical of the region. Larvae of fall and winter spawners (cisco, lake whitefish, burbot, fourhorn sculpin) appeared first, followed by larvae of spring spawners (yellow perch, suckers, rainbow smelt). Larvae of summer spawners including alewife, carp, cyprinids and centrarchids appeared last.

The shallow inshore littoral zone, from 2 m to less than 0.5 m deep, harbors concentrations of larvae and is often proclaimed an important nursery area for fish. The gear employed in this study provides some of the first quantitative estimates of larval abundance in these regions. Since 1979, the ichthyoplankton program has increased to sample important areas which may be affected by excessive sedimentation as well as winter and summer navigation.

Efforts to collect coregonid larvae at four stations in 1981 immediately following ice-out in April and May yielded a total of 74 cisco and 58 lake whitefish larvae from 75 pull net, fifty-eight 0.5 m net, and forty-eight 1.0 m net collections. The majority of the lake whitefish (71%) larvae were taken from the shallow littoral at Station 5. Cisco larvae were abundant in the shallow littoral of Stations 5 and 9, with few coregonid larvae being taken in Lake George with any gear type. Peak density of cisco and lake whitefish larvae in the spring collections occurred on 20 April at Station 5 (50/100 m^3 and 238/100 m^3, respectively).

Comparison of Lake Nicolet (Station 5) and Lake George data suggest that nearshore differences in habitat (temperature regimes, vegetation and substrate type) may help to explain differences in species composition and abundance. Consequently it was not possible to determine if differences in larval fish abundance could be attributed to effects of navigation. The shallow inshore area of Lake George was dominated by cyprinid larvae, ranging from 50 to 72% of the total catch. In Lake Nicolet, the shallow inshore areas were dominated by percids (yellow perch, logperch, johnny darter and other darters), comprising 30 - 60% of the total catch. Cyprinid larvae in Lake Nicolet accounted for only 4 - 20% of the total catch in the shallow vegetated areas. Offshore or channel collections in both Lake George and Lake Nicolet were dominated by rainbow smelt larvae, representing 75 and 85% of the catch, respectively. Overall, water temperatures in Lake George were higher than Lake Nicolet.

During the 1981 field season, the highest observed density along the emergent macrophyte beds (1,559/100 m^3) occurred at Station 9 on 9 June, with rainbow smelt comprising 99% of the catch. In the shallow littoral zone (less than 0.5 m deep), maximum density of larvae (4,487/100 m^3) was observed at Station 9 on 7 July. At this time, sucker larvae were the predominant taxon.

In general, species composition and relative abundance of fish larvae was similar in the St. Marys River in 1979, 1980 and 1981. Variability is high among and within stations during the same year, as is variability among years. The development of additional sampling gear which effectively sampled new habitats in 1980 and 1981 yielded higher numbers of larvae, however, no new taxa were recorded in any great numbers. Isolated "marsh" areas of the littoral zone have not been quantitatively sampled in the St. Marys River for larval fish, however. These areas are thought to be spawning and nursery areas for northern pike, bowfin, carp, bluegill, pumpkinseed and smallmouth bass.

The differences seen among stations in composition and abundance of larval fish reflect utilization of a mosaic of habitats by fish for nursery areas within the river system. All habitats may not contribute the same amount to the recruitment of individual populations. The alterations, if any, imposed by dredging or navigation activities would be expected to affect larval fish populations through effects on the littoral zone, namely through loss of habitat in the form of submersed and emergent macrophytes and subsequent food availability and cover they provide. In addition, lateral transport of larvae along the littoral zone during the drawdown and surge action of the water during vessel passage has an effect on survival of larval fish. These impacts remain speculative, however.

JUVENILE AND ADULT FISH

Gill Nets

Experimental bottom gill nets were employed in the St. Marys River system during 1981 to gather baseline data on species composition, indices of abundance (catch per effort) and lengths of juvenile and adult fishes. Collections were taken at shallow and deep sites of Navigation Courses 5, 7 and 9, and in a non-shipped area, Lake George. Comparisons were made among depths, stations, and between years.

Each gill net consisted of seven individual 15.2 x 1.8 m (50' x 6') panels of 25 (1"), 51 (2"), 63 (2½"), 76 (3"), 102 (4"), 114 (4½"), and 178 mm (7", 104 twine size) stretched mesh nylon of No. 69 twine size. Nets were identical to those fished during 1979 and 1980.

During winter, forty-three 24-hour gill net sets collected 310 fish of 12 species in Navigation Courses 5 and 7. Catch per effort was 7.29. White sucker comprised 42.5% of the catch, while cisco contributed 35.5%. Other important species included yellow perch (6.5%), northern pike (4.5%), and burbot (4.5%). Cisco were captured primarily in nets set near the navigation channel. White sucker, yellow perch and northern pike were captured primarily

in nearshore nets. The winter catch per effort increased substantially over the 1980 value as a response to significant increases in catch rate of white sucker and cisco. Length frequency modes for dominant species were roughly similar during winter between years.

A total of 78 net sets during open water seasons in Navigation Courses 5, 7 and 9 captured 1,742 fish of 26 species. Dominant species were white sucker (25.5%), cisco (21.9%), yellow perch (17.2%), northern pike (11.9%), rock bass (7.6%), and walleye (7.6%). Spring samples were dominated by white sucker, northern pike, cisco, and yellow perch. White sucker, northern pike, and yellow perch were frequently captured during summer. Cisco and walleye were occasionally captured in high numbers, primarily during July. Fall sample dominants were white sucker, northern pike, yellow perch, and rock bass. November collections contained significant numbers of cisco. Nearshore nets yielded higher catch per effort values at all stations than those nets set nearest the ship channel.

A total of 28 gill net sets made during open water seasons in Lake George collected 652 fish of 22 species (catch per effort = 23.2). The catch was dominated by white sucker (30.5%), northern pike (21.8%) and yellow perch (20.2%). Northern pike, yellow perch, and white sucker dominated catches in spring, summer and fall. Rock bass and walleye were collected frequently in July. Small catches of pink salmon and cisco were noted in fall. Catch per effort for all species combined was higher in Lake George compared to Lake Nicolet. Cisco, rock bass, and walleye exhibited higher CPE values in Lake Nicolet.

Catch per effort comparisons for 1980 vs. 1981 indicated a general decline in 1981. Cisco evidenced the greatest decline in CPE between years. Percent composition of catch was roughly similar with the order of dominance of white sucker and cisco switched between years.

Direct effects, if any, of excessive sedimentation, ice breaking, and ship passage on juvenile and adult fishes would probably be wrought primarily upon physiological processes (respiration, growth, reproduction, development and maturation). Other effects may include changes in movement patterns, spatial and temporal abundance, alteration of habitats and changes in linkage and structure of the supporting food webs. Effects of winter navigation related activities appear to be transient with the exception of channel dredging which could have a long-term effect by reducing available fish habitat in the Middle Neebish Channel and reducing colonizable substrate for benthic organisms thereby adversely affecting forage densities.

Small Mesh Trap Nets

Small mesh trap nets were used to sample fish populations in the upper littoral zone of the St. Marys River. These nets were constructed with 6.35 mm (.25") bar mesh nylon webbing. Each net had a 15.2 x 1 m (50 x 3.3') lead, 2.2 x 1 m (7.2 x 3.3') wings, 1 m^2 (10.8 ft^2) pot and a single heart. Twelve hour samples were collected both during night and day periods. Seasonal sampling was conducted in emergent vegetation and open areas of the upper littoral zone in Navigation Courses 5, 7 and 9, and in Lake George, a non-shipping channelized lake area within the St. Marys River system.

A total of 8,103 fish representing 42 species were taken in 82 trap net collections in Navigation Courses 5, 7 and 9 (CPE = 98.8). Bluegill was the most abundant species (28.5% of the total catch). Other major species included brown bullhead (13.6%), yellow perch (12.8%), bluntnose minnow (11.3%), and white sucker (7.8%). Species abundance and composition of these collections varied with season, time of day and station.

A total of 11,769 fish of 35 species were taken in 36 trap net collections (CPE = 326.9) in Lake George. Spottail shiner was the most abundant species (51.5% of total catch). Other major species included common shiner (25.0%), yellow perch (6.6%), bluntnose minnow (3.3%) and black crappie (2.3%). Species composition of collections in Lake George varied with season and time of day.

Fish populations using the upper littoral zone of Lake George were numerically larger than fish populations in the other areas sampled. A comparable navigated area (Navigation Course 5) contained fewer fish (CPE = 68.7) than Lake George (CPE = 326.9). Of the sport fishes, yellow perch, smallmouth bass, largemouth bass, northern pike and white sucker were more abundant in Lake George while brown bullhead and bluegill were more abundant in Navigation Course 5. Forage fish also had larger populations in Lake George than Navigation Course 5.

Considerable annual variability of species abundance at comparable sampling locations was largely due to year class strength. The upper littoral zone is an important nursery area for both juvenile sport and forage fishes. In addition, many adult fishes frequent the shallow waters of the upper littoral zone.

The impacts of the proposed season extension are speculative. Turbulence under ice cover from passing vessels may injure fish or disrupt normal behavior. Increases in suspended solids may also impair normal feeding behavior. The emergent vegetation of the upper littoral zone is important to juvenile fish populations and ice scouring of over-wintering rootstock systems of macrophytes would reduce preferred habitat.

Trawls

Bottom trawl samples were taken in the St. Marys River system during 1981 to gather baseline data on species composition and abundance indices of juvenile and adult fishes. The trawl was a semi-balloon otter trawl having a 4.9 m (16') head rope, 38 mm (1.5") stretch mesh body and 3 mm (.1") bar mesh cod end liner. Samples were collected at night in nearshore (1.5 m) and offshore (3.1 m) sites within Navigation Courses 5, 7 and 9, and in a non-shipping area, Lake George. A total of 10 samples were taken at each station during May through October. Comparisons were made among depths, stations and between years.

A total of 5,997 fish of 28 species were collected in 30 trawl samples from Navigation Courses 5, 7 and 9. Johnny darters were most abundant, comprising 19.3% of the total catch. Other numerically important species included ninespine stickleback (12.3%), trout-perch (11.8%), yellow perch (9.2%), spottail shiner (7.1%) and mottled sculpin (6.4%). Total catch per

effort at Course 5 was approximately half that at either Course 7 or 9. Overall catch in the offshore areas was greater than in the nearshore areas at Courses 7 and 9, but the opposite was true in Course 5. Depth distribution of individual species varied from station to station and by date.

A total of 3,234 fish representing 23 species were collected in 10 trawl samples from Lake George. Trout-perch were most abundant, making up 36.2% of the total catch followed by spottail shiner (19.1%), yellow perch (15.6%), johnny darter (10%) and common shiner (4.4%). White sucker made up only 3.8% of the catch by number but represented nearly 44% of the catch by weight. Overall, more specimens were taken in the deep near-channel area compared to the shallow nearshore area of Lake George. Trout-perch were consistently captured in greatest numbers at the deep station, while johnny darters, Iowa darters, yellow perch and rock bass were more abundant nearshore. Brook stickleback occurred only in the shallow samples.

The fish community represented by the trawl samples was slightly more diverse in Lake George as compared to Course 5 and overall CPE in Lake George was more than three times greater than at Course 5. Trout-perch, johnny darters, spottail shiners, white suckers, yellow perch, smelt, Iowa darter, brook stickleback, bluntnose minnows and common shiners were much more abundant in Lake George. Rock bass, slimy sculpins, brown bullheads and mimic shiners were each at least twice as abundant in samples from Course 5 as compared to Lake George.

Overall CPE decreased by about 10% from 1980 to 1981 in Courses 7 and 9. Catch per effort of smelt, ninespine sticklebacks and logperch increased significantly from 1980 to 1981. While other species exhibited sometimes drastic changes in CPE, these changes were not statistically significant due to variability of the data. Relative abundances of the major species shifted noticeably from 1980 to 1981. The community was dominated by trout-perch, spottail shiners and johnny darters in 1980, and together the three species made up over 60% of the total catch. In 1981 the order of importance changed to johnny darters, ninespine stickleback, yellow perch and trout-perch, respectively, and these species comprised 56% of the total number caught.

All species sampled by trawls are either spring or summer spawners and there would be little danger of egg destruction from winter shipping. Problems associated with winter shipping could possibly be associated with disruption of submerged and emergent aquatic plant beds which are spawning sites for some of the species. Also, increased sedimentation may cause added mortalities to eggs or larvae.

Any discussion of possible reduction in the fish community should be tempered with considerations of compensation by the population in question. Decreased reproduction may lead to increased survival of young of successful spawners. Also, reduction of fish production from one area may be off-set by immigration from other sites, if sufficient habitat remains unaffected by winter navigation activities.

PHYSICAL AND CHEMICAL ASPECTS

Water Chemistry, Temperature and Turbidity

Water temperature, dissolved oxygen, turbidity, dissolved solids and pH were measured in conjunction with biological sampling in nearshore and offshore sites of Navigation Courses 5, 7 and 9, and Lake George of the St. Marys River during 1981.

Water temperatures were near $0^{o}C$ during winter, began increasing in May, and reached maximum values of 19 - $24^{o}C$ in late summer, all sites considered. Nearshore areas were warmer in spring and summer compared to offshore areas. The reverse was true for fall. Lake George was warmer than other stations during spring and fall.

Dissolved oxygen values from 298 total measurements ranged from 3.5 - 13.9 ppm. Most readings were >9 ppm. Lowered values occurred during summer at nearshore sites.

Turbidity values ranged from 0.7 - 120 NTU. Turbidities were generally highest during fall and at nearshore sites. Lake George experienced higher turbidities than all other sites.

Dissolved solids generally remained fairly constant at all sites, though this parameter exhibited a total range of 22 - 175 ppm. However, only 3 percent of all measurements were outside a range of 50 - 80 ppm.

No major differences in pH values among sites occurred. Summer offshore pH readings indicated basic conditions while fall offshore readings indicated acidic conditions. A range of 4.8 - 9.2 S.U. occurred, which was larger than reported in 1980 studies.

The parameter most likely to be effected significantly by winter navigation activities would be turbidity because of potential increases in suspended solids carried by the river.

Winter Sedimentation Rates

Sediment traps were developed and used to collect baseline winter sedimentation data in the St. Marys River to be compared to winter sedimentation data during future commercial shipping and channel modification activities. Lake George, not involved in commercial navigation, was chosen to act as a control.

Samples were collected in off-channel areas of Navigation Courses 5 and 7 during 3 February to 24 March 1981, and in Lake George during approximately the same period. Sediment traps were composed of 30.5 cm cylinders with inside diameters of 2.5 cm, which resulted in an aspect ratio of 12. Trapped sediments were filtered, dryed and weighed over two exposure periods (mid-winter, late winter). Organic/inorganic fractions were determined for sediments collected during the second exposure period.

Sedimentation rates were greater in Lake George (927 - 6,315 $mg/m^2/d$) than in either Course 5 (138 - 592 $mg/m^2/d$) or Course 7 (296 - 592 $mg/m^2/d$) during mid-winter. During late winter sedimentation rates at Courses 5 and 7 increased (296 - 1,342 $mg/m^2/d$). However, sedimentation rates in Lake George (631 - 1,184 $mg/m^2/d$) also averaged more than other areas during late winter. Inorganic content of collected sediments was high, averaging 87.3 - 100% in samples. Turbidity measurements taken during the period indicated a possible positive correlation with sedimentation rates.

Any winter commercial shipping and/or channel modifications that increase the sediment loading in the St. Marys River should be reflected in increased sedimentation in off-channel areas, which, in turn, would be measurable with the sediment traps. However, the site chosen in Lake George as a control does not appear satisfactory with regard to monitoring sedimentation.

Sediment Chemistry of Shipping and Non-Shipping Channels

Sediment cores were collected during June 1981 from an active shipping channel (Lake Nicolet) and an inactive shipping channel (Lake George) in the St. Marys River and analyzed for 21 parameters, including nutrients, heavy metals, organic compounds, total solids, volatile solids and particle size. All parameters except two occurred in higher average concentrations in the shipping channel. According to USEPA Region V criteria, the same parameters exceeded moderate pollution levels at both sites, while those non-polluted were so at both sites, and those below detectability were so at both sites, seeming to indicate shipping was not the source of contaminants in Lake Nicolet sediments.

Lake Nicolet sediments had higher clay and organic matter levels, and their affinity for heavy metals and organic chemicals may be the cause of higher levels of constituents. Additionally, higher sedimentation rates in Lake George may bury contaminated sediments there resulting in less polluted levels. These factors, rather than shipping, appear as the most likely reasons for the differences between the two channels. Many other factors, such as redox potential, sediment pH, bacteria, sulfur and iron cycles, not examined in this study, may also strongly effect the contaminant levels of sediments.

LITERATURE CITED

Allen, H. E. 1976. Metal speciation in aquatic environments, pp. 35-58. In Robert W. Andrew, Peter V. Holson and Dennis E. Konasewich (eds.), Proceedings of Workshops sponsored by International Joint Commission, October, 1975, Duluth, Minnesota.

American Public Health Association. 1971. Standard Methods for the Examination of Water and Wastewater, 13th ed. APHA, New York.

American Public Health Association. 1975. Standard Methods for the Examination of Water and Wastewater, 14th ed. APHA, New York.

Amundrud, J. R., D. J. Faber, and A. Keast. 1974. Seasonal succession of free-swimming perciform larvae in Lake Opinicon, Ontario. J. Fish. Res. Bd. Can. 31:1661-1665.

Anderson, R. C. 1979. Temporal changes in relative abundance, distribution and food habits of shoreline fishes near the Ludington plant. Ph.D. Dissertation. Mich. State Univ. In preparation.

Bailey, J. E. 1952. Life history and ecology of the sculpin *Cottus bairdi punctulatus* in southwestern Montana. Copeia 1952(4):243-255.

Bailey, M. M. 1972. Age, growth and reproduction of the burbot, *Lota lota*, in southwestern Lake Superior. Trans. Am. Fish. Soc. 101:667-674.

Barnes, R. K. and K. H. Mann (eds.). 1980. Fundamentals of aquatic ecosystems. Blackwell Scientific Pub., Oxford. 229 pp.

Beamish, R. J. and H. H. Harvey. 1969. Age determination in the white sucker. J. Fish. Res. Bd. Can. 26:633-638.

Beck, W. M., Jr. 1977. Environmental requirements and pollution tolerance of common freshwater Chironomidae. U.S. Envir. Prot. Agency, Envir. Monitor. and Support Lab., Pub. No. EPA-600/4-77-024. 261 pp.

Bell, E. 1981. St. Marys River discharge and flow distribution measurements, 1965-1979. U.S. Army Corps of Eng. 20 pp.

Beltz, J. R., J. E. Johnson, D. L. Cohen, and F. B. Pratt. 1974. An annotated bibliography of the effects of temperature on fish, with special reference to the freshwater and anadromous species of New England. Mass. Agr. Exp. Sta., Bull. No. 605, Univ. Mass. 97 pp.

Black, J. D. 1945. Natural history of the northern mimic shiner, Notropis volucellus volucellus Cope. Invest. Indiana Lakes Streams 2(18):449-469.

Bloesch, J. and N. M. Burns. 1980. A critical review of sedimentation trap technique. Schweiz. Z. Hydrol. 42/1, 15-55.

Bousfield, E. L. 1958. Fresh-water amphipod crustaceans of glaciated North America. Can. Field-Nat. 72:55-113.

Braum, E. 1967. The survival of fish larvae in reference to their feeding behavior and the food supply, pp. 113-131. In Gerking, S. D. (ed.). The biological basis of freshwater fish production. Blackwell, Oxford and Edinburgh.

Brazo, D. C. 1973. Fecundity, food habits, and certain allometric features of the yellow perch (Perca flavescens Mitchill) before operation of a pumped storage plant on Lake Michigan. M.S. Thesis, Mich. St. Univ. 75 pp.

Brittain, J. E. 1982. Biology of mayflies. Ann. Rev. Entomol. 27:119-147.

Burch, J. B. and C. M. Patterson. 1976. Key to the genera of freshwater pelecypods (mussels and clams) of Michigan. Mus. of Zool., Univ. Mich., Ann Arbor, Circ. No. 4, 38 pp.

Campbell, R. S. 1935. A study of the common sucker, Catostomus commersoni (Lacepede), of Waskesiv Lake, M.S. Thesis, Dept. of Biology, Univ. of Saskatchewan, Saskatoon, Sask. 48 pp.

Cassie, R. M. 1969. Statistical aspects of sampling and recording data. In R. A. Vollenweider (ed.). A manual on methods for measuring primary production in aquatic environments. IBP Handbook No. 12. Blackwell Scientific Pub., Oxford. 213 pp.

Clifford, H. 1972. Downstream movements of white sucker, Catostomus commersoni, fry in a brownwater stream of Alberta. J. Fish. Res. Bd. Can. 29:1091-1093.

Colby, R. J., and L. T. Brooke. 1969. Cisco (Coregonus artedii) mortalities in a southern Michigan Lake, July 1968. Limnol. Oceanogr. 14:958-960.

Cooper, J. E. 1978a. Identification of eggs, larvae, and juveniles of rainbow smelt, Osmerus mordax, with comparisons to larval alewife, Alosa pseudoharengus, and gizzard shad, Dorosoma cepedianum. Trans. Am. Fish. Soc. 107(1):56-62.

______. 1978b. Eggs and larvae of the logperch, Percina caprodes (Rafinesque). Am. Midl. Nat. 99(2):257-269.

Cordone, A. J. and D. Kelley. 1961. The influence of organic sediment on the aquatic life of streams. Calif. Fish and Game 47:189-228.

Dames and Moore. 1978. Assessment of Fisheries Resource and Impacts for the Sault Ste. Marie Deepwater Harbor Project. Public Works Can., Ontario Region. 64 pp.

Diana, J. S. 1979. The feeding pattern and daily ration of a top carnivore, the northern pike (Esox lucius). Can. J. Zool. 57:2121-2127.

______, and W. C. Mackay. 1979. Timing and magnitude of energy deposition and loss in the body, liver, and gonads of northern pike (Esox lucius). J. Fish. Res. Bd. Can. 36:481-487.

Dorr, J. A. III, D. J. Jude, F. J. Tesar and N. J. Thurber. 1976. Identification of larval fishes taken from inshore waters of southeastern Lake Michigan near the Donald C. Cook Nuclear Plant, 1973-1975, pp. 61-82. In J. Boreman (ed.), Great Lakes Fish Egg and Larvae Identification: Proceedings of a Workshop. U.S. Fish and Wildlife Service. FWS/OBS-76/23.

Duncan, T. O. 1978. Collection bucket for use with tow nets for larval fish. Prog. Fish-Cult. 40(3):118-119.

Dunning, D. and Q. Ross. 1982. Evaluation of minimum size limits for St. Lawrence River northern pike. No. Am. J. of Fish. Manag. 2(2):171-175.

______, M. J. Tarby, and J. T. Evans. 1978. Adult fisheries study. Tech. Rep. D. In J. W. Geis (ed.). Environmental assessment of the FY 1979 winter navigation demonstration on the St. Lawrence River. SUNY College of Environmental Science and Forestry, Syracuse, New York, USA.

Dymond, J. R. 1926. The fishes of Lake Nipigon. Univ. Toronto Stud. Biol. Ser. 27, Publ. Ont. Fish. Res. Lab. 27:1-108.

Edmunds, G. F., Jr., S. L. Jensen, and L. Berner. 1976. The mayflies of North and Central America. Univ. Minn. Press, Minneapolis. 330 pp.

Edsall, T. A., and P. J. Colby. 197C. Temperature tolerance of young-of-the-year cisco, Coregonus artedii. Trans. Am. Fish. Soc. 99(3):526-531.

Elliott, J. M. 1977. Some methods for the statistical analysis of samples of benthic invertebrates, 2nd ed. Freshwater Biol. Assoc. Pub. No. 25. 156 pp.

El-Zarka, S. E. D. 1959. Fluctuations in the population of yellow perch Perca flavescens (Mitchill) in Saginaw Bay, Lake Huron. U.S. Fish Wildl. Serv. Fish. Bull. 59:365-415. In J. J. Ney. 1978. A synoptic review of yellow perch and walleye biology.

Engle, S. and J. J. Magnuson. 1976. Vertical and horizontal distributions of coho salmon (Oncorhynchus kisutch), yellow perch (Perca flavescens, and cisco (Coregonus artedii) in Pallette Lake, Wisconsin. J. Fish. Res. Bd. Canada. 33(12):2710-2719.

Faber, D. 1970. Ecological observations on newly hatched lake whitefish in South Bay, Lake Huron, pp. 481-500. In C. C. Lindsey and C. S. Woods (eds.), Biology of Coregonid Fishes. Univ. of Manitoba Press, Winnipeg.

Ferguson, R. G. 1965. Bathymetric distribution of American smelt, Osmerus mordax, in Lake Erie. Great Lakes Res. Div. Univ. Mich. Publ. 13:47-60. In W. B. Scott and E. J. Crossman. 1973. Freshwater Fishes of Canada.

Fish, M. P. 1932. Contributions to the early life histories of fish from Lake Erie and its tributary waters. U.S. Bur. Fish., Bull. 47:293-398.

Fleischer, G. 1981. Personal communication, St. Marys River sedimentation rate project.

Gale, W. F. and H. W. Mohr, Jr. 1978. Larval fish drift in a large river with a comparison of sampling methods. Trans. Am. Fish. Soc. 107(1):46-55.

Galloway, J. E. and N. R. Kevern. 1976. Michigan Suckers: Their life histories, abundance, and potential for harvest. Tech. Rept. No. 53, MICH-SG-206, Mich. Sea Grant Prog., Ann Arbor, Mich. 46 pp.

Gardner, M. B. 1981. Effects of turbidity on feeding rates and selectivity of bluegills. Trans. Am. Fish. Soc. 110:446-450.

Geen, G., T. Northcote, G. Hartman, and C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteenmile Lake, British Columbia, with particular reference to inlet stream spawning. J. Fish. Red. Bd. Can. 23:1761-1788.

Gerrish, N. and J. M. Bristow. 1979. Macroinvertebrate associations with aquatic macrophytes and artificial substrates. J. Great Lakes Res. 5(1):69-72.

Gill, J. L. 1978. Design and analysis of experiments in the animal and medical sciences. Iowa State Univ. Press, Ames, Iowa, 386 pp.

Gleason, G. R., D. J. Behmer and K. L. Vincent. 1979. Evaluation of benthic dislocation due to pressure waves initiated by vessel passage in the St. Marys River. 23 pp. and appendicies.

______, D. J. Behmer, and R. Hook. 1979. Evaluation of lake whitefish and herring spawning grounds as they may be affected by excessive sedimentation induced by vessel entrapment due to the ice environment within the St. Marys River system. The Environmental Work Group FY 1979 Studies of the Winter Navigation Demonstration Program, U.S. Corps of Engineers, Detroit District.

Graser, L. F. 1978. Flow-through collection bucket for larval fish. Prog. Fish-Cult. 40(2):78-79.

Greely, J. R. 1927. Fishes of the Genesee Region with annotated list, pp. 47-66. In A biological survey of the Genesee River system. Suppl. 16th Ann. Rep. N.Y. Conserv. Dept. 1926. 100 pp.

Hach, C. C. 1974. Introduction to turbidity measurement, 2nd ed. Hach Chem. Co., Ames, Iowa. 14 pp.

Hamdy, Y., J. D. Kinkead and M. Griffiths. 1978. St. Marys River Water Quality Investigations 1973-74. Ontario Ministry of the Envir., Water Res. Branch, Great Lakes Survey Unit. 53 pp.

Hansen, M. J. and D. H. Wahl. 1981. Selection of small Daphnia pulex by yellow perch fry in Oneida Lake, New York. Trans. Am. Fish. Soc. 110(1):64-71.

Hargrave, B. T. and N. M. Burns. 1979. Assessment of sediment trap collection efficiency. Limno. Oceanogr. 24, 1124-1135.

Heard, W. H. and J. B. Burch. 1966. Key to the Genera of Freshwater Pelecypods (Mussels and Clams) of Michigan. Univ. of Mich., Museum of Zool. Circ. No. 4. 14 pp.

Heard, W. R. 1965. Limnetic cottid larvae and their utilization as food by juvenile sockeye salmon. Trans. Am. Fish. Soc. 94:191-193.

Heimstra, N. D., D. K. Damkot and N. G. Benson. 1969. Some effects of silt turbidity on behavior of juvenile largemouth bass and green sunfish. Tech. Pap. 20. U.S. Bur. Sport Fish. and Wildl., Washington, D.C.

Hergenrader, G. L. and A. D. Hasler. 1968. Influence of changing seasons on schooling behavior of yellow perch. J. Fish. Res. Bd. Can. 25(4):711-716.

Hilsenhoff, W. L. 1975. Aquatic Insects of Wisconsin: With generic keys and notes of biology, ecology and distribution. Tech. Bull. No. 89, Dept. Nat. Res., Madison, Wis. 53 pp.

Holsinger, J. R. 1976. The freshwater amphipod crustaceans (Gammaridae) of North America. U.S. Envir. Prot. Agency. Envir. Monitor and Support Lab. Pub. No. 18050 ELD04/72. 89 pp.

Hogue, J. J., R. Wallus, and L. K. Kay. 1976. Preliminary guide to the identification of larval fishes in the Tennessee River. TVA Tech. Note B 19. Dec. 1976. 66 pp.

Hungerford, H. B. 1948. The Corixidae of the Western Hemisphere (Hemiptera). Univ. Kan. Sci. Bull. 32:5-827.

Hutchinson, G. E. 1967. A Treatise on Limnology - II. Introduction to Lake Biology and the Limnoplankton. John Wiley and Sons, N.Y. 1115 pp.

Hynes, H. B. and M. J. Coleman. 1968. A simple method for assessing the annual production of stream benthos. Limnol. Oceanogr. 13:569-582.

International Lake Superior Board of Control. 1974. Feasibility study of remedial works in the St. Marys Rapids at Sault Ste. Marie. Report to the International Joint Commission.

Janssen, J. 1978. Feeding-behavior repertoire of the alewife, *Alosa pseudoharengus*, and the ciscoes *Coregonus hoyi* and *C. artedii*. J. Fish. Res. Bd. Can. 35:249-253.

Kavaliers, M. 1980. Circadian activity of the white sucker, *Catostomus commersoni*; comparison of individual and shoaling fish. Can. J. Zool. 58:1399-1403.

Keast, A. 1965. Resource subdivisions amongst cohabiting fish species in a bay, Lake Opinicon, Ontario. Proc. 8th Conf. Great Lakes Res. Div. Univ. Mich. 106-132.

_____. 1968. Feeding of some Great Lakes fishes at low temperatures. J. Fish. Res. Bd. Can. 22:1357-1377.

_____, and D. Webb. 1966. Mouth and body form relative to feeding ecology in the fish fauna of a small lake, Lake Opinicon, Ontario. J. Fish. Res. Bd. Can. 23(12):1845-1867.

_____, and L. Welsh. 1968. Daily feeding periodicities, food uptake rates, and dietary changes with hour of day in some lake fishes. J. Fish. Res. Bd. Can. 25(6)1133-1144.

Kelso, J. R. M. and F. J. Ward. 1977. Unexploited percid populations of West Blue Lake, Manitoba and their interactions. J. Fish. Res. Bd. Canada. 34:1655-1669.

Kenaga, D. 1978. Biological survey of the St. Marys River, June 19 and 20, 1978. Preliminary Staff Rep. Mich. Dept. Nat. Res. 9 pp.

_____. 1979. A biological and chemical survey of the St. Marys River in the vicinity of Sault Ste. Marie, June 19-20, 1978. Water Qual. Div., Mich. Dept. Nat. Res.

Kinkead, J. D. and R. M. Chatterjee. 1974. A limnological survey of nearshore waters of Lake Superior. Proc. 17th Conf. Great Lakes Res., Int. Assoc. Great Lakes Res., 549-573.

Kitchell, J. F., M. G. Johnson, C. K. Minns, K. H. Loftus, L. Grieg, and C. H. Oliver. 1977. Percid habitat: the river analogy. J. Fish. Res. Bd. Can. 34:1936-1940.

Koehler, F. E. 1979. Life history studies of the longnose sucker, Catostomus catostomus, and the white sucker, Catostomus commersoni, in nearshore eastern Lake Michigan near Ludington, Michigan. M.S. Thesis, Mich. State Univ. 56 pp.

Koster, W. J. 1936. The life-history and ecology of the sculpins (Cottidae) of central New York. Ph.D. Thesis. Cornell Univ., Ithaca, N.Y.

Lam, C. N. H. and J. C. Roff. 1977. A method for separating alewife, Alosa pseudoharengus, from gizzard shad, Dorosoma cepedianum, larvae. J. Great Lakes Res. 3(3-4):313-316.

Lawler, G. H. 1954. Observations on the trout-perch Percopsis omiscomaycus (Walbaum), at Hemming Lake, Manitoba. J. Fish. Res. Bd. Can. 11(1):1-4.

_____. 1963. The biology and taxonomy of burbot, Lota lota, in Hemming Lake, Manitoba. J. Fish. Res. Bd. Can. 20:417-433.

Lawrie, A. H. 1978. The fish community of Lake Superior. J. Great Lakes Res. 4:513-549.

Lee, G. F. and R. H. Plumb. 1974. Literature review on research study for the development of dredged material disposal criteria. Univ. of Texas-Dallas. 145 pp.

Levin, S. A. 1976. Spatial patterning and the structure of ecological communities. In Some Mathematical Questions in Biology. Vol. 7, ed. S. A. Levin. Lectures on Mathematics in the Life Sciences, Vol. 8. Providence, Rhode Island, Am. Math. Soc.

_____, and R. T. Paine. 1974. Disturbance, patch formation, and community structure. Proc. Natl. Acad. Sci. USA 71:2744-2747.

Lippson, A. J. and R. L. Moran. 1974. Manual for identification of early developmental stages of fishes of Potomac River estuaries. Marietta Corp. Spec. Publ. PPSP-MP-13. 282 pp.

Liston, C. R., W. G. Duffy, D. E. Ashton, C. D. McNabb and F. E. Koehler. 1980. Environmental baseline and evaluation of the St. Marys River dredging. Mich. State Univ., Dept. Fish. Widl. Rep. to U.S. Fish Wildl. Serv., FWS/OBS-80/62. 295 pp.

_____, W. G. Duffy, D. E. Ashton, T. Batterson and C. D. McNabb. 1981. Supplementary environmental baseline studies and evaluation of the St. Marys River, 1980. Mich. State Univ., Dept. Fish. Wildl. Rep. to U.S. Fish. Wildl. Serv., FWS/OBS-80/62.1. 167 pp.

Long, W. L. and W. W. Ballard. 1976. Normal embryonic stages of the white sucker, Catostomus commersoni. Copeia, 1976. No. 2:342-351.

Magnuson, J. L. and L. L. Smith. 1963. Some phases of the life history of the trout-perch. Ecology 44(1):83-95.

Mansueti, A. J. 1964. Early development of the yellow perch, Perca flavescens, Ches. Sci. 5(1-2):46-66.

_____, and J. D. Hardy. 1967. Development of fishes of the Chesapeake Bay Region. An atlas of egg, larval, and juvenile stages. Part 1. Univ. of Maryland, Baltimore. 202 pp.

May, E. B. and C. R. Gasaway. 1967. A preliminary key to the identification of larval fishes of Oklahoma, with particular reference to Canton Reservoir including a selected bibliography. Oklahoma Fish. Res. Lab. Bull. No. 5. Norman, Okla. 42 pp.

Mayhew, J. 1956. The bluegill, Lepomis macrochirus (Rafinesque), in West Okoboji Lake, Iowa. Proc. Iowa Acad. Sci. 63:705-713.

McCann, J. A. 1959. Life history studies of the spottail shiner of Clear Lake, Iowa, with particular reference to some sampling problems. Trans. Am. Fish. Soc. 88(4):336-343.

McCarraher, D. B. and R. E. Thomas. 1972. Ecological significance of vegetation to northern pike, Esox lucius, spawning. Trans. Am. Fish. Soc. 101(3):560-563.

McCormick, J. H., B. R. Jones, and K. E. F. Hokanson. 1977. White sucker (Catostomus commersoni) embryo development and early growth and early survival at different temperatures. J. Fish. Res. Bd. Can. 34:1019-1025.

McFadden, J. T. 1976. Environmental impact assessment for fish populations, pp. 89-137. In R. R. Sharma, J. D. Buffington, and J. T. McFadden (eds.), The Biological Significance of Environmental Impacts. U.S. Dept. of Commerce, Natl. Tech. Inform. Serv. PB-258-563. 327 pp.

_____. 1977. An argument supporting the reality of compensation in fish populations and a plea to let them exercise it. pp. 153-183. In W. VanWinkle (ed.), Proceedings of the Conference on Assessing the Effects of Power-plant Induced Mortality on Fish Populations, May 3-6, 1977. Ann Arbor, MI. Pergamon Press, New York. 380 pp.

Menzie, C. A. 1981. Production ecology of Cricotopus sylvestris (Fabricius) (Diptera: Chironomidae) in a shallow estuarine cove. Limnol. Oceanogr. 26:467-481.

Merritt, R. W. and K. W. Cummins (eds.) 1978. An introduction to the aquatic insects of North America. Kendall/Hunt, Dubuque, Iowa. 441 pp.

Meyer, F. A. 1970. Development of some larval centrarchids. Prog. Fish-Cult. 32(3):130-136.

Miller, B. A. 1981. A 1979 fisheries survey of the St. Marys River system in Chippewa County, and comparisons with 1976 results. Mich. Dept. Nat. Res., Fish. Div. Tech. Rept. No. 81-1. 24 pp.

Moffett, J. W. and B. P. Hunt. 1943. Winter feeding habits of bluegills, Lepomis macrochirus (Rafinesque), and yellow perch, Perca flavescens (Mitchill), in Cedar Lake, Washtenaw County, Michigan. Trans. Am. Fish. Soc. 73:231-242.

Morton, J. W. 1977. Ecological effects of dredging and dredge spoil disposal: A Literature Review. U.S. Fish and Wildl. Serv. Tech. Pap. 94. 33 pp.

Moyle, P. B. 1973. Ecological segregation among three species of minnows (Cyprinidae) in a Minnesota Lake. Trans. Am. Fish. Soc. 102(4):794-805.

Nelson, W. R. 1968. Embryo and larval characteristics of sauger, walleye and their reciprocal hybrids. Trans. Am. Fish. Soc. 97(2):167-174.

Ney, J. J. 1978. A synoptic review of yellow perch and walleye biology. Am. Fish. Soc. Spec. Publ. 11:1-12.

Norden, C. R. 1961. The identification of larval yellow perch, Perca flavescens, and walleye, Stizostedion vitreum. Copeia, 1961(3):282-288.

_____. 1967. Development and identification of the larval alewife, Alosa pseudoharengus, (Wilson), in Lake Michigan. Proc. 10th Conf. on Great Lakes Res.: 70-78.

Ontario Ministry of the Environment. 1981. A history of the pollution control programme at the Algoma Steel Corporation Limited in Sault Ste. Marie, Ontario. Ministry of the Environment, Northeastern Region. 30 pp.

Pearce, W. A. 1961. The upper St. Lawrence River ice fishery. New York Fish and Game Journal. 8:31-36.

Pennak, R. W. 1978. Freshwater Invertebrates of the United States, 2nd ed. John Wiley and Sons. New York. 803 pp.

Poe, T. P., T. A. Edsall and J. K. Hiltunen. 1979. Effects of ship-induced waves in an ice environment on the St. Marys River ecosystem. Rept. Proj. No. 5100, Great Lakes Basin Comm. 24 pp. and appendices.

Priegel, G. 1970. Reproduction and early life history of the walleye in the Lake Winnebago Region. Wis. Dept. Nat. Resour. Tech. Bull. 45. 105 pp.

Raney, E. C. and E. A. Lachner. 1942. Studies of the summer food, growth, and movements of young yellow pike-perch, Stizostedion v. vitreum, in Oneida Lake, New York. J. Wildl. Manage. 6(1):1-16.

_____, and B. W. Menzel. 1969. Heated effluents and effects on aquatic life with emphasis on fishes - a bibliography. Cornell Univ. Water Res. and Marine Sci. Cent., Phil. Elec. Co., and Ichthyological Assoc., Bull. No. 2, 468 pp.

Rawson, D. S. 1957. The life history of the yellow walleye, Stizostedion vitreum, in Lac la Ronge, Saskatchewan. Trans. Am. Fish. Soc. 86:15-37.

Ricker, W. E. 1934. An ecological classification of certain Ontario streams. Univ. Toronto Stud. Biol. Ser. 37, Publ. Ont. Fish. Res. Lab. 49:114 pp.

_____. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Bd. Can. Bull. 191, 352 pp.

Ryder, R. A. and S. R. Kerr. 1978. The adult walleye in the percid community - a niche definition based on feeding behavior and food specificity. Am. Fish. Soc. Spec. Publ. 11:39-51.

Savage, T. 1963. Reproductive behavior of the mottled sculpin, Cottus bairdi Girard. Copeia 1963(2):317-325.

Schneider, J. C. and J. H. Leach. 1977. Walleye (Stizostedion vitreum vitreum) fluctuations in the Great Lakes and possible causes, 1800-1975. J. Fish. Res. Bd. Can. 34:1878-1889.

Scott, W. B. and E. J. Crossman. 1973. Freshwater Fishes of Canada. Fish. Res. Bd. Can. Bull. 184. 966 pp.

Sheldon, A. A. 1968. Drift, growth and mortality of juvenile sculpins in Sagehen Creek, California. Trans. Am. Fish. Soc. 7(4):495-496.

Sherk, J. A., J. M. O'Connor, D. A. Newmann, R. D. Prince, and K. V. Wood. 1974. Effects of suspended and deposited sediments on estuarine organisms, Phase II. Final report U.S. Amy Corps of Eng. Cont. No. DACW72-71-C-003. Univ. Md., Nat. Res. Inst. Ref. No. 74-20. 410 pp. In E. M. Stern and W. B. Stickle. 1978. Effects of turbidity and suspended material in aquatic environments. Literature Review.

Sinclair, D. C. 1968. Diel limnetic occurrence of young Cottus asper in two British Columbia lakes. J. Fish. Res. Bd. Can. 25(9):1997-2000.

Smith, L. L., Jr. and R. H. Kramer. 1964. The spottail shiner of Lower Red Lake, Minnesota. Trans. Am. Fish. Soc. 93(1):35-45.

Spoor, W. A., and C. L. Schloemer. 1938. Diurnal activity of the common sucker, Catostomus commersoni (Lacepede), and the rock bass, Ambloplites rupestris (Rafinesque), in Muskellunge Lake. Trans. Am. Fish. Soc. 68:211-220.

Starrett, W. C. 1950. Food relationships of the minnows of the Des Moines River, Iowa. Ecology 31(2):216-233.

Stern, E. M. and W. B. Stickle. 1978. Effects of turbidity and suspended material in aquatic environments. Literature review. Dredged Material Res. Prog. Tech. Rept. D-78-21. 118 pp.

Swanson, G. A., G. L. Krapu and J. R. Serie. 1979. Foods of laying female dabbling ducks on the breeding grounds, pp. 47-57. In T. A. Bookout (ed.), Waterfowl and Wetlands - an integrated review. LaCrosse Printing Company, Inc., LaCrosse, Wis. 147 pp.

Tarplee, W. H., W. T. Bryson, and R. G. Sherfinski. 1979. Portable push-net apparatus for sampling ichthyoplankton. Prog. Fish-Cult. 41(4):213-215.

U.S. Environmental Protection Agency. 1977. Guidelines for the pollution classification of Great Lakes harbor sediments. USEPA, Region V, Chicago, Ill. 7 pp.

Veal, D. M. 1968. Biological survey of the St. Marys River. Ont. Water Res. Comm. in cooperation with International Joint Commission. 23 pp. plus tables.

Waters, T. F. 1977. Secondary production in inland waters. Adv. Ecol. Res. 10:91-164.

_____, and J. C. Hokenstrom. 1980. Annual production and drift of the stream amphipod Gammarus pseudolimnaeus in Valley Creek, Minnesota. Limnol. Oceanogr. 25:700-710.

Wells, L. and A. L. McLain. 1973. Lake Michigan: Man's effects on native fish stocks and other biota. Great Lakes Fish Comm. Tech. Rept. No. 20. 55 pp.

Werner, E. E., D. J. Hall and M. D. Werner. 1978. Littoral zone fish communities of two Florida lakes and a comparison with Michigan lakes. Env. Biol. Fish. 3(2):163-172.

Wetzel, R. G. 1976. Limnology. W. B. Saunders, Philadelphia. 743 pp.

Wiens, J. A. 1976. Population responses to patchy environments. Ann. Rev. Ecol. Syst. 7:81-120.

Wilber, C. G. 1971. Turbidity, pp. 1157-1194. In O. Kinne (ed.). Marine ecology: a comprehensive integrated treatise on life in oceans and coastal waters, Vol. 1, Part 2. Wiley-Interscience. In E. M. Stern and W. B. Stickle. 1978. Effects of turbidity and suspended material in aquatic environments. Literature review.

Williams, W. D. 1976. Freshwater isopods (Asellidae) of North America. USEPA, Biota of Freshwater Ecosystems Identification Manual No. 8. 45 pp.

Winn, H. E. 1958. Observations on the reproductive habits of darters (Pisces-Percidae). Amer. Midland Natur. 59(1):190-212.

Wright, A. T. and R. Schorffaar. 1976. Summary of August, 1975, St. Marys River synoptic fish survey. Mich. Dept. Nat. Res., Fish. Div. 14 pp.

Appendix A. Abundance estimates (number/m^2) of benthic macroinvertebrates determined from all samples taken in the St. Marys River during 1981.

Table A1. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 7, St. Marys River during June 1981.

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
EPHEMEROPTERA					
Caenis sp.	21	0	0	0	14
Ephemera sp.	140	14	14	7	56
Hexagenia sp.	749	511	0	168	147
TRICHOPTERA					
Helicopsyche sp.	7	0	0	0	7
Molanna sp.	7	0	0	0	0
Mystacides sp.	7	7	0	56	0
Nectopsyche sp.	0	28	0	0	0
Oecetis sp.	0	7	0	0	0
Phryganea sp.	0	0	7	0	0
Polycentropus sp.	28	21	0	56	7
Trianodes sp.	0	0	0	14	0
COLEOPTERA					
Haliplus sp. (A)	0	0	7	0	0
DIPTERA					
Ceratopogonidae	763	1,204	287	1,330	28
Chironomidae					
Cladotanytarsus sp.	496	0	98	1,204	777
Cryptochironomus sp.	2,527	3,108	0	0	0
Larsia sp.	710	5,407	140	140	525
Monodiamesa sp.	213	0	0	0	0
Paracladopelma sp.	0	0	0	21	1,554
Parachironomus sp.	0	0	0	84	0
Polypedilum sp.	0	3,184	1,827	7,882	315
Procladius sp.	998	798	140	448	462
Psectrocladius sp.	0	1,383	0	0	0

Continued

Table A1. Continued

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
Stictochironomus sp.	0	0	0	28	63
Chironomidae pupae	84	63	0	322	7
AMPHIPODA					
Hyalella azteca	13	357	0	0	14
ISOPODA					
Asellus sp.	0	49	0	14	0
Lirceus sp.	0	245	0	63	7
DECAPODA	0	0	7	0	0
HYDRACARINA	56	35	0	14	56
TURBELLARIA	0	140	0	14	0
GASTROPODA					
Amnicola sp.	581	49	0	0	287
Gyraulus sp.	0	14	0	0	0
Helisoma sp.	0	0	0	7	0
Physa sp.	0	49	0	0	0
Valvata sp.	77	77	0	0	35
PELECYPODA					
Pisidium sp.	13	14	0	0	0
Sphaerium sp.	13	56	0	0	7
POLYCHAETA					
Manayunkia sp.	14	0	0	0	7
HIRUDINEA	0	7	0	7	0
OLIGOCHAETA	2,191	4,525	1,162	1,281	3,136

Continued

Table A1. Concluded

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
NEMATODA	1,358	1,064	490	175	7
COELENTERATA					
Hydra sp.	0	0	14	0	0
OSTRACODA	0	0	0	0	14
TOTAL	11,066	22,340	4,186	13,335	7,539

Table A2. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 7, St. Marys River during September 1981.

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
EPHEMEROPTERA					
Ameletus sp.	252	0	0	0	0
Caenis sp.	0	0	0	0	7
Ephemera sp.	221	14	0	0	0
Hexagenia sp.	1,911	441	0	105	98
Leptophlebia sp.	21	0	0	105	0
TRICHOPTERA					
Helicopsyche sp.	7	0	0	0	0
Mystacides sp.	0	49	0	21	0
Oecetis sp.	42	0	0	0	0
Oxyethira sp.	0	0	0	0	21
Phryganea sp.	0	28	0	0	7
Phylocentropus sp.	63	0	0	0	0
Polycentropus sp.	0	56	0	0	21
Trianodes sp.	0	0	0	21	63
HEMIPTERA					
Corixidae	0	7	0	0	0
MEGALOPTERA					
Sialis sp.	0	0	0	0	7
DIPTERA					
Ceratopogonidae	1,323	735	35	924	420
Tabanidae	0	0	7	0	
Chironomidae					
Ablabesmyia sp.	0	2,184	0	0	49
Chironomus sp.	0	0	217	0	
Clinotanypus sp.	0	0	0	42	
Coelotanypus sp.	2,205	0	0	0	28
Cricotopus sp.	0	0	0	7	

Continued

Table A2. Continued

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
Cryptochironomus sp.	567	0	0	0	0
Cryptocladopelma sp.	0	0	42	0	966
Larsia sp.	1,428	0	28	2,793	651
Monodiamesa sp.	21	21	0	0	105
Paracladopelma sp.	315	567	0	0	0
Phaenospectra sp.	0	63	0	189	672
Polypedilum sp.	315	203	49	1,827	2,506
Potthastia sp.	7	126	0	0	0
Procladius sp.	1,092	784	7	777	602
Psectrocladius sp.	0	0	350	21	0
Stictochironomus sp.	0	0	0	7	70
Tanytarsus sp.	42	525	0	651	0
AMPHIPODA					
Hyalella azteca	0	623	7	168	448
Gammarus sp.	0	0	0	0	7
ISOPODA					
Asellus sp.	21	49	0	0	651
Lirceus sp.	0	371	0	147	413
DECAPODA	0	0	0	7	7
HYDRACARINA	0	70	7	84	399
GASTROPODA					
Amnicola sp.	0	42	0	0	77
Gyraulus sp.	0	63	0	0	147
Physa sp.	0	91	0	42	112
Valvata sp.	0	56	0	0	0
PELECYPODA					
Pisidium sp.	0	0	0	0	7

Continued

Table A2. Concluded

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
HIRUDINEA	0	0	0	0	7
OLIGOCHAETA	1,638	735	231	3,759	651
OSTRACODA	0	0	0	0	105
NEMATODA	0	0	0	0	21
TOTAL	11,491	7,903	980	11,697	9,345

Table A3. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 9, St. Marys River during June 1981.

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
EPHEMEROPTERA					
Ephemera sp.	406	0	0	0	77
Ephemerella sp.	0	35	0	0	0
Hexagenia sp.	49	56	49	644	0
Isonychia sp.	0	14	0	0	0
TRICHOPTERA					
Molanna sp.	7	0	0	0	14
Mystacides sp.	0	21	0	0	0
Oecetis sp.	14	0	7	0	14
Phryganea sp.	0	7	0	0	0
Phylocentropus sp.	0	42	0	28	0
Polycentropus sp.	0	7	0	0	0
Rhyacophila sp.	0	0	7	0	0
MEGALOPTERA					
Sialis sp.	0	0	0	42	105
DIPTERA					
Ceratopogonidae	378	84	42	210	28
Empididae	0	0	7	0	0
Chironomidae					
Chironomus sp.	0	98	0	0	0
Cladotanytarsus sp.	1,554	0	0	126	0
Cryptochironomus sp.	56	0	7	0	7
Dicrotendipes sp.	0	0	0	112	0
Larsia sp.	595	1,274	147	222	0
Monodiamesa sp.	42	7	28	1,428	56
Paracladopelma sp.	70	0	0	0	0
Polypedilum sp.	560	2,590	7	0	0
Procladius sp.	980	1,190	21	4,004	658

Continued

Table A3. Continued

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
Psectrocladius sp.	0	7	7	0	0
Pseudosmittia sp.	490	0	0	0	0
Stempelina sp.	280	0	7	0	0
Stictochironomus sp.	3,990	161	0	0	112
Tanypus sp.	0	609	0	0	434
Chironomidae pupae	56	42	35	14	0
AMPHIPODA					
Hyalella azteca	0	119	0	0	7
Gammarus sp.	0	14	0	0	0
ISOPODA					
Asellus sp.	0	84	0	0	0
Lirceus sp.	0	210	0	0	0
DECAPODA	0	21	0	0	0
HYDRACARINA	140	70	28	35	0
GASTROPODA					
Amnicola sp.	364	21	0	105	35
Goniobasis sp.	14	0	0	0	0
Gyraulus sp.	168	112	0	21	21
Physa sp.	322	238	0	49	91
Pleurocerca sp.	7	0	0	0	0
Valvata sp.	0	0	0	0	21
PELECYPODA					
Pisidium sp.	0	7	0	0	42
Sphaerium sp.	28	0	651	7	42
POLYCHAETA					
Manayunkia sp.	1,400	140	0	0	0

Continued

Table A3. Concluded

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
OLIGOCHAETA	791	2,562	245	1,190	252
NEMATODA	2,100	280	0	84	0
COELENTERATA					
Hydra sp.	0	70	0	0	0
TOTAL	14,861	10,192	1,295	8,321	2,016

Table A4. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 9, St. Marys River during September 1981.

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
EPHEMEROPTERA					
Caenis sp.	504	0	0	7	168
Ephemera sp.	147	21	0	0	21
Ephemerella sp.	0	7	0	0	0
Hexagenia sp.	828	147	0	266	1,029
TRICHOPTERA					
Lepidostoma sp.	7	7	0	0	0
Mystacides sp.	21	0	0	42	0
Oecetis sp.	7	0	0	0	42
Oxyethira sp.	0	0	0	21	0
Phryganea sp.	0	0	0	7	0
Phylocentropus sp.	21	189	0	105	0
Polycentropus sp.	63	21	0	0	0
HEMIPTERA					
Corixidae	0	21	0	21	0
COLEOPTERA					
Haliplus sp.	7	0	0	0	0
Macronychus sp.	0	0	7	0	0
DIPTERA					
Ceratopogonidae	588	294	63	308	294
Stratiomyidae	0	0	21	0	0
Tabanidae	0	0	28	0	0
Chironomidae					
Ablabesmyia sp.	14	77	0	42	21
Clinotanypus sp.	0	21	0	49	0
Cricotopus sp.	0	0	210	0	0
Cryptochironomus sp.	945	7	21	0	0
Dicrotendipes sp.	504	0	0	0	378

Continued

Table A4. Continued

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
Epoicocladius sp.	0	21	0	7	0
Larsia sp.	1,554	672	224	2,394	4,410
Microspectra sp.	63	28	0	0	0
Monodiamesa sp.	56	0	0	0	0
Parachironomus sp.	0	0	420	0	63
Paracladopelma sp.	0	126	0	525	0
Paratanytarsus sp.	69	0	0	0	0
Polypedilum sp.	3,234	476	105	882	441
Potthastia sp.	105	0	0	0	0
Procladius sp.	1,358	182	0	1,029	798
Stictochironomus sp.	63	1,358	84	1,995	21
Tanytarsini	7	0	0	0	0
AMPHIPODA					
Hyalella azteca	840	133	0	665	357
Gammarus sp.	0	0	0	7	420
ISOPODA					
Asellus sp.	0	28	0	210	0
Lirceus sp.	462	140	7	672	0
HYDRACARINA	84	7	0	49	126
TURBELLARIA	7	21	7	0	0
GASTROPODA					
Amnicola sp.	126	0	0	21	42
Gyraulus sp.	7	56	0	126	0
Pluerocerca sp.	7	0	0	0	0
Physa sp.	7	63	0	98	42
Valvata sp.	21	0	0	42	147

Continued

Table A4. Concluded

TAXA	WEST SHALLOW	WEST DEEP	CHANNEL	EAST DEEP	EAST SHALLOW
PELECYPODA					
Anodonta sp.	0	0	7	0	0
Pisidium sp.	7	0	0	0	0
Sphaerium sp.	21	0	7	0	42
POLYCHAETA					
Manayunkia sp.	0	0	756	0	0
HIRUDINEA	84	0	0	0	21
OLIGOCHAETA	2,058	434	441	1,596	2,961
OSTRACODA	0	0	0	0	21
NEMATODA	0	0	0	546	672
TOTAL	13,886	4,557	2,408	11,732	12,579

Table A5. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 5, St. Marys River during April 1981.

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Ephemera sp.	791	0
Ephemerella sp.	189	7
Hexagenia sp.	35	0
TRICHOPTERA		
Lepidostoma sp.	7	0
Molanna sp.	0	129
Mystacides sp.	35	0
Neuroclipsis sp.	14	0
Polycentropus sp.	7	32
Hydroptila sp.	0	14
Trianodes sp.	7	32
COLEOPTERA		
Haliplus sp.	7	0
ODONATA		
Enallagma sp.	0	32
LEPIDOPTERA		
Nymphula sp.	21	0
DIPTERA		
Ceratopogonidae	35	323
Simulidae	14	21
Chironomidae		
Ablabesmyia sp.	14	0
Cricotopus sp.	294	0
Diamesa sp.	0	248

Continued

Table A5. Continued

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
Epoicocladius sp.	70	0
Heterotrissocladius sp.	42	0
Larsia sp.	154	187
Monodiamesa sp.	126	435
Polypedilum sp.	511	2,183
Procladius sp.	154	687
Prodiamesa sp.	301	0
Stictochironomus sp.	0	561
Tanytarsus sp.	0	1,061
Tribelos sp.	42	0
AMPHIPODA		
Hyalella azteca	497	32
Gammarus sp.	0	148
ISOPODA		
Asellus sp.	7	0
Lirceus sp.	7	65
HYDRACARINA	0	46
TURBELLARIA	14	32
GASTROPODA		
Amnicola sp.	490	46
Ferrissia sp.	0	98
Gyraulus sp.	7	7
Valvata sp.	70	0
PELECYPODA		
Sphaerium sp.	49	0

Continued

Table A5. Concluded

TAXA	STATION: 3M DEPTH	STATION: VEGETATED LITTORAL ZONE
HIRUDINEA	0	129
OLIGOCHAETA	1,988	7,760
TOTAL	6,027	14,315

Table A6. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 5, St. Marys River during June 1981.

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Ameletus sp.	0	21
Caenis sp.	0	172
Ephemera sp.	42	0
Hexagenia sp.	221	0
TRICHOPTERA		
Ceraclea sp.	7	43
Polycentropus sp.	77	0
HEMIPTERA		
Corixidae	0	42
LEPIDOPTERA		
Nymphula sp.	0	42
DIPTERA		
Ceratopogonidae	951	0
Chironomidae		
Cladotanytarsus sp.	0	126
Coelotanypus sp.	217	0
Conchapelopia sp.	0	147
Cricotopus sp.	1,365	0
Cryptochironomus sp.	28	43
Dicrotendipes sp.	0	714
Larsia sp.	945	43
Monodiamesa sp.	7	0
Parachironomus sp.	7	0
Paracladopelma sp.	273	0
Polypedilum sp.	6,216	86

Continued

Table A6. Concluded

TAXA	STATION: 3M DEPTH	STATION: VEGETATED LITTORAL ZONE
Procladius sp.	658	580
Psectrocladius sp.	0	42
Stictochironomus sp.	189	0
Tanytarsini	84	129
Tribelos sp.	77	0
Trissocladius sp.	469	860
Chironomidae pupae	98	42
AMPHIPODA		
Hyalella azteca	1,617	252
Gammarus sp.	0	43
ISOPODA		
Asellus sp.	0	408
Lirceus sp.	126	0
HYDRACARINA	0	21
GASTROPODA		
Amnicola sp.	42	21
Lymnaea sp.	0	21
Physa sp.	21	0
Valvata sp.	14	0
PELECYPODA		
Sphaerium sp.	56	0
HIRUDINEA	7	0
OLIGOCHAETA	1,974	1,346
TOTAL	15,788	5,244

Table A7. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 5, St. Marys River during August 1981.

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Ameletus sp.	0	7
Caenis sp.	7	883
Hexagenia sp.	182	0
TRICHOPTERA		
Ceraclea sp.	14	0
Oxyethira sp.	0	7
Platycentropus sp.	0	7
Polycentropus sp.	0	121
HEMIPTERA		
Corixidae	7	21
ODONATA		
Enallagma sp.	0	112
LEPIDOPTERA		
Paraponyx sp.	0	7
DIPTERA		
Ceratopogonidae	56	0
Chironomidae		
Ablabesmyia sp.	0	630
Clinotanypus sp.	0	43
Cricotopus sp.	21	0
Cryptochironomus sp.	0	42
Dicrotendipes sp.	0	178

Continued

Table A7. Continued

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
Epoicocladius sp.	21	0
Larsia sp.	7	630
Microspectra sp.	28	788
Microtendipes sp.	0	890
Monodiamesa sp.	7	0
Paracladopelma sp.	98	0
Polypedilum sp.	1,050	1,015
Potthastia sp.	7	0
Procladius sp.	868	214
Psectrocladius sp.	546	98
Stictochironomus sp.	0	77
Tanytarsus sp.	0	1,223
Tribelos sp.	21	1,223
Chironomidae pupae	28	0
AMPHIPODA		
Hyalella azteca	294	276
Gammarus sp.	56	78
ISOPODA		
Asellus sp.	0	3,191
Lirceus sp.	256	0
HYDRACARINA	0	114
GASTROPODA		
Amnicola sp.	168	0
PELECYPODA		
Sphaerium sp.	14	0

Continued

Table A7. Concluded

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
HIRUDINEA	0	155
OLIGOCHAETA	1,344	1,060
COELENTERATA		
Hydra sp.	0	105
NEMATODA	0	105
OSTRACODA	0	630
TOTAL	5,096	13,930

Table A8. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 5, St. Marys River during October 1981.

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Caenis sp.	210	1,003
Callibaetis sp.	0	84
Ephemera sp.	189	0
Hexagenia sp.	588	28
Leptophlebia sp.	14	0
TRICHOPTERA		
Lepidostoma sp.	21	0
Leptoceridae	0	105
Mystacides sp.	21	0
Oecetis sp.	21	0
Phryganea sp.	0	43
Phylocentropus sp.	0	7
Polycentropus sp.	140	351
Trianodes sp.	84	7
HEMIPTERA		
Trichocorixa sp.	56	0
Sigara sp.	7	77
ODONATA		
Enallagma sp.	0	121
LEPIDOPTERA		
Paraponyx sp.	0	7
Nymphula sp.	0	7

Continued

Table A8. Continued

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
DIPTERA		
Ceratopogonidae	819	115
Athericidae	0	14
Chironomidae		
Ablabesmyia sp.	7,602	86
Corynoneura sp.	0	420
Cricotopus sp.	210	1,064
Cryptochironomus sp.	777	525
Epoicocladius sp.	0	430
Larsia sp.	0	3,430
Parachironomus sp.	1,470	0
Paratanytarsus sp.	0	11,586
Polypedilum sp.	2,121	2,150
Procladius sp.	707	1,462
Pseudochironomus sp.	0	1,075
Stictochironomus sp.	0	523
Tanytarsus sp.	42	0
Tribelos sp.	490	1,161
AMPHIPODA		
Hyalella azteca	3,619	2,492
Gammarus sp.	21	163
ISOPODA		
Asellus sp.	7	462
Lirceus sp.	287	444
GASTROPODA		
Amnicola sp.	217	129

Continued

Table A8. Concluded

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
Ferrissia sp.	0	7
Gyraulus sp.	42	79
Physa sp.	35	49
PELECYPODA		
Sphaerium sp.	0	43
POLYCHAETA		
Manayunkia sp.	0	253
HIRUDINEA	0	100
OLIGOCHAETA	3,843	2,651
OSTRACODA	210	100
NEMATODA	210	0
COELENTERATA		
Hydra sp.	210	0
TOTAL	24,654	32,853

Table A9. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 5, St. Marys River during December 1981.

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Caenis sp.	0	1,070
Callibaetis	0	21
Ephemera sp.	105	29
Hexagenia sp.	119	43
Leptophlebia sp.	21	14
TRICHOPTERA		
Leptoceridae	0	430
Phylocentropus sp.	0	21
Polycentropus sp.	189	0
Trianodes sp.	42	43
HEMIPTERA		
Sigara sp.	0	996
ODONATA		
Enallagma sp.	0	43
LEPIDOPTERA		
Paraponyx sp.	0	21
DIPTERA		
Ceratopogonidae	686	72
Chironomidae		
Ablabesmyia sp.	1,050	21
Cladotanytarsus sp.	0	1,470
Cricotopus sp.	0	3,010
Cryptochironomus sp.	252	573
Dicrotendipes sp.	763	258

Continued

Table A9. Continued

TAXA	STATION: 3M DEPTH	STATION: VEGETATED LITTORAL ZONE
Larsia sp.	2,331	2,560
Monodiamesa sp.	210	43
Paratanytarsus sp.	0	86
Polypedilum sp.	3,052	3,483
Potthastia sp.	210	0
Procladius sp.	1,743	1,767
Psectrocladius sp.	0	57
Stictochironomus sp.	0	387
Tanytarsus sp.	77	172
AMPHIPODA		
Hyalella azteca	2,919	1,547
Gammarus sp.	70	176
ISOPODA		
Asellus sp.	35	1,075
Lirceus sp.	490	687
HYDRACARINA	112	121
TURBELLARIA	63	77
GASTROPODA		
Amnicola sp.	63	1,261
Ferrissia sp.	0	63
Gyraulus sp.	49	0
Helisoma sp.	21	0
Physa sp.	42	28
Valvata sp.	21	0

Continued

Table A9. Concluded

TAXA	STATION: 3M DEPTH	STATION: VEGETATED LITTORAL ZONE
PELECYPODA		
Pisidium sp.	0	7
Sphaerium sp.	63	0
HIRUDINEA	0	72
OLIGOCHAETA	994	1,012
OSTRACODA	1,050	5,611
NEMATODA	420	0
TOTAL	17,292	28,427

Table A10. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Navigation Course 5, St. Marys River during March 1981.

TAXA	NAVIGATION CHANNEL
EPHEMEROPTERA	
Hexagenia sp.	4
TRICHOPTERA	
Polycentropus sp.	4
DIPTERA	
Empididae	8
Chironomidae	
Cladotanytarsus sp.	4
Cricotopus sp.	196
Larsia sp.	4
Orthocladius sp.	122
AMPHIPODA	
Hyalella azteca	4
HYDRACARINA	4
POLYCHAETA	
Manayunkia sp.	10
OLIGOCHAETA	25
TOTAL	385

Table A11. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Lake George, St. Marys River during April 1981.

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Ephemera sp.	63	0
Ephemerella sp.	0	65
Hexagenia sp.	784	0
TRICHOPTERA		
Mystacides sp.	14	0
Neureclipsis sp.	0	32
Phylocentropus sp.	56	0
Polycentropus sp.	21	0
Hydroptila sp.	0	65
Trianodes sp.	49	32
DIPTERA		
Ceratopogonidae	308	0
Tipulidae	0	7
Chironomidae		
Ablabesmyia sp.	407	0
Cricotopus sp.	203	886
Dicrotendipes sp.	510	443
Epoicocladius sp.	52	0
Larsia sp.	2,085	0
Polypedilum sp.	813	0
Procladius sp.	203	0
Psectrocladius sp.	0	220
Rheotanytarsus sp.	0	1,106
Stempelina sp.	0	443
Stictochironomus sp.	52	0

Continued

Table A11. Concluded

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
AMPHIPODA		
Hyalella azteca	14	7
Gammarus sp.	112	0
ISOPODA		
Asellus sp.	7	0
Lirceus sp.	301	0
TURBELLARIA	7	0
GASTROPODA		
Amnicola sp.	28	0
Helisoma sp.	7	0
Physa sp.	7	0
PELECYPODA		
Pisidium sp.	357	0
Sphaerium sp.	56	0
HIRUDINEA	7	0
OLIGOCHAETA	77	467
TOTAL	6,600	3,773

Table A12. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Lake George, St. Marys River during June 1981.

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Ameletus sp.	0	485
Caenis sp.	231	774
Ephemera sp.	84	0
Hexagenia sp.	693	0
TRIPCHOPTERA		
Mystacides sp.	21	0
Oecetis sp.	63	0
Phylocentropus sp.	21	0
LEPIDOPTERA		
Nymphula sp.	0	21
DIPTERA		
Ceratopogonidae	63	0
Empididae	0	7
Chironomidae		
Ablabesmyia sp.	273	126
Cladotanytarsus sp.	0	4,257
Corynoneura sp.	0	7
Cricotopus sp.	0	252
Cryptochironomus sp.	861	0
Dicrotendipes sp.	0	231
Larsia sp.	210	430
Microtendipes sp.	0	86
Parachironomus sp.	105	0
Polypedilum sp.	483	0
Procladius sp.	504	0
Psectrocladius sp.	0	210
Chironomidae pupae	7	21

Continued

Table A12. Concluded

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
AMPHIPODA		
Hyalella azteca	42	557
Gammarus sp.	0	43
HYDRACARINA	7	63
GASTROPODA		
Amnicola sp.	1,197	0
Gyraulus sp.	21	0
Valvata sp.	84	0
PELECYPODA		
Anodonta sp.	7	0
Pisidium sp.	1,491	0
OLIGOCHAETA	1,365	5,048
TOTAL	7,833	12,618

Table A13. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Lake George, St. Marys River during August 1981.

TAXA	STATION: 3M DEPTH	STATION: VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Caenis sp.	0	71
Ephemera sp.	0	21
Hexagenia sp.	686	0
TRICHOPTERA		
Phryganea sp.	56	0
Phylocentropus sp.	56	0
Platycentropus sp.	0	21
Polycentropus sp.	0	43
Trianodes sp.	0	7
HEMIPTERA		
Trichocorixa sp.	0	70
Immature Corixidae	0	42
Notonecta sp.	0	7
COLEOPTERA		
Dineutus sp.	0	21
ODONATA		
Arigomphus sp.	0	7
Enallagma sp.	0	7
Epicordulia sp.	0	7
Libellula sp.	0	7
DIPTERA		
Ceratopogonidae	105	21
Chironomidae		
Ablabesmyia sp.	294	224
Clinotanypus sp.	0	7

Continued

Table A13. Continued

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
Cryptochironomus sp.	63	86
Dicrotendipes sp.	0	84
Epoicocladius sp.	35	0
Polypedilum sp.	434	392
Procladius sp.	189	21
Psectrocladius sp.	273	507
Stictochironomus sp.	0	265
Chironomidae pupae	14	7
AMPHIPODA		
Hyalella azteca	378	273
Gammarus sp.	0	7
ISOPODA		
Asellus sp.	14	35
Lirceus sp.	504	0
HYDRACARINA	28	162
TURBELLARIA	0	43
GASTROPODA		
Amnicola sp.	196	0
Gyraulus sp.	0	7
Physa sp.	14	42
PELECYPODA		
Pisidium sp.	42	0
Sphaerium sp.	196	0
HIRUDINEA	0	64

Continued

Table A13. Concluded

TAXA	STATION	
	3M DEPTH	VEGETATED LITTORAL ZONE
OLIGOCHAETA	1,092	2,730
OSTRACODA	0	14
TOTAL	3,619	4,584

Table A14. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Lake George, St. Marys River during October 1981.

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Caenis sp.	63	898
Ephemera sp.	98	21
Hexagenia sp.	161	43
Leptophlebia sp.	210	42
TRICHOPTERA		
Helicopsyche borealis	0	21
Molanna sp.	7	0
Mystacides sp.	112	0
Oecetis sp.	21	70
Phryganea sp.	21	0
Phylocentropus sp.	70	0
Polycentropus sp.	147	21
Setodes sp.	21	0
Trianodes sp.	35	0
ODONATA		
Arigomphus sp.	0	107
Ashna sp.	0	42
Enallagma sp.	0	113
LEPIDOPTERA		
Nymphula sp.	7	21
DIPTERA		
Ceratopogonidae	112	903
Chironomidae		

Continued

Table A14. Continued

	STATION	
TAXA	3M DEPTH	VEGETATED LITTORAL ZONE
Ablabesmyia sp.	252	881
Cladotanytarsus sp.	0	3,870
Clinotanypus sp.	0	344
Cryptochironomus sp.	21	0
Dicrotendipes sp.	630	1,290
Endochironomus sp.	0	7
Larsia sp.	287	7,510
Paratanytarsus sp.	0	21
Polypedilum sp.	350	210
Procladius sp.	63	917
Psectrocladius sp.	0	210
Stictochironomus sp.	0	229
Tanytarsus sp.	0	86
Tribelos sp.	0	161
AMPHIPODA		
Hyalella azteca	2,436	1,023
Gammarus sp.	21	43
ISOPODA		
Asellus sp.	112	215
Lirceus sp.	259	0
HYDRACARINA	273	28
TURBELLARIA	84	0
GASTROPODA		
Amnicola sp.	420	0
Goniobasis sp.	7	0

Continued

Table A14. Concluded

TAXA	STATION: 3M DEPTH	STATION: VEGETATED LITTORAL ZONE
Gyraulus sp.	21	0
Physa sp.	42	0
Valvata sp.	0	43
PELECYPODA		
Pisidium sp.	189	0
Sphaerium sp.	1,456	21
HIRUDINEA	7	21
OLIGOCHAETA	1,344	5,117
OSTRACODA	0	6,086
NEMATODA	0	1,490
TOTAL	9,359	32,125

Table A15. Abundance estimates (number/m^2) for benthic macroinvertebrates collected from Lake George, St. Marys River during December 1981.

TAXA	STATION: 3M DEPTH	STATION: VEGETATED LITTORAL ZONE
EPHEMEROPTERA		
Caenis sp.	168	2,780
Ephemera sp.	539	0
Hexagenia sp.	1,869	21
Leptophlebia sp.	35	253
TRICHOPTERA		
Mystacides sp.	21	0
Oecetis sp.	14	29
Oxyethira sp.	0	21
Phylocentropus sp.	21	0
Polycentropus sp.	189	122
Trianodes sp.	21	0
HEMIPTERA		
Trichocorixa sp.	0	217
ODONATA		
Enallagma sp.	0	21
Libellula sp.	0	7
LEPIDOPTERA		
Nymphula sp.	0	1,120
DIPTERA		
Ceratopogonidae	1,120	2,389
Chironomidae		
Ablabesmyia sp.	3,675	3,223
Cryptochironomus sp.	336	683

Continued

Table A15. Continued

TAXA	STATION	
	3M DEPTH	VEGETATED LITTORAL ZONE
Dicrotendipes sp.	378	215
Endochironomus sp.	0	86
Paratanytarsus sp.	273	2,201
Polypedilum sp.	5,229	4,514
Potthastia sp.	63	0
Procladius sp.	1,302	1,099
Psectrocladius sp.	0	1,890
Smittia sp.	0	7
Stictochironomus sp.	0	21
AMPHIPODA		
Hyalella azteca	742	1,362
Gammarus sp.	0	21
ISOPODA		
Asellus sp.	0	484
Lirceus sp.	42	427
HYDRACARINA	91	21
TURBELLARIA	7	72
GASTROPODA		
Amnicola sp.	105	353
Ferrissia sp.	0	1,050
Gyraulus sp.	0	43
Valvata sp.	7	14
PELECYPODA		
Sphaerium sp.	42	210

Continued

Table A15. Concluded

TAXA	STATION 3M DEPTH	STATION VEGETATED LITTORAL ZONE
HIRUDINEA	0	7
OLIGOCHAETA	1,722	11,493
TOTAL	18,011	36,476

Appendix B. Measurements of height, number, and biomass of submerged and emergent aquatic plants in the St. Marys River during 1981.

Table B1. Measurements from inshore portion of *Scirpus acutus* bed on Lake George transect in 1981. Mean values given in the table. Where two entries are made in a column for a date, the second is 1 standard error; n = 10.

	Scirpus acutus				Secondary Species[1]								Sample Totals		
Date	Height (m)	No. Shoots m^{-2}	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Height (m) Ef	Height (m) Es	No. Shoots m^{-2} Ef	No. Shoots m^{-2} Es	Dry Weight $g\ m^{-2}$ Ef	Dry Weight $g\ m^{-2}$ Es	Ash-Free Dry Weight $g\ m^{-2}$ Ef	Ash-Free Dry Weight $g\ m^{-2}$ Es	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Other[1] Species Present
6/3	1.0	140	174	165	0.4	0.3	26	14	11	1	9	1	187	176	
		14	15	14			10	7	3	1	3	1	14	13	
7/6	1.8	138	489	467	0.8	1.0	49	50	30	26	26	24	550	522	Tsp, Sl
		14	43	41			10	19	7	9	6	9	35	33	
8/11	1.7	158	575	553	0.8	0.8	60	62	39	32	35	30	649	619	Sl
		13	35	33			11	30	7	16	6	15	39	38	
9/4	1.8	157	556	524	0.7	0.8	19	21	13	9	11	8	577	543	
		11	38	35			6	8	4	3	4	3	34	31	

1. Species designated as Ef = *Equisitum fluviatile*, Es = *Eleocharis smallii*, Sl = *Sagittaria latifolia*, Tsp = *Typha sp*.

Table B2. Measurements from offshore portion of *Scirpus acutus* bed on Lake George transect in 1981. Mean values given in the table. Where two entries are made in a column for a date, the second is 1 standard error; n = 10.

	Scirpus acutus				Secondary Species[1]								Sample Totals		
Date	Height (m)	No. Shoots m^{-2}	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Height (m) Ef	Height (m) Es	No. Shoots m^{-2} Ef	No. Shoots m^{-2} Es	Dry Weight $g\ m^{-2}$ Ef	Dry Weight $g\ m^{-2}$ Es	Ash-Free Dry Weight $g\ m^{-2}$ Ef	Ash-Free Dry Weight $g\ m^{-2}$ Es	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Other[1] Species Present
6/3	0.5	53	26	23	0.3		4		0.8		0.7		27	24	
		8	4	4					0.4		0.4		4	3	
7/6	1.5	93	257	239		0.8		9		5		5	263	244	Ef
		9	27	24				4		2		2	27	25	
8/11	1.7	76	248	238		1		48		40		38	288	276	Ef
		5	18	17				14		13		12	20	20	
9/4	1.7	74	281	269		1		20		20		19	301	287	
		5	24	23				8		7		7	23	21	

1. Species designated as Ef = *Equisitum fluviatile*, Es = *Eleocharis smallii*.

Table B3. Measurements from *Isoetes riparia* bed on Lake George transect in 1981. Mean values given in the table. Where two entries are made in a column for a date, the second is 1 standard error; n = 10.

	Isoetes riparia				Secondary Species[1]								Sample Totals		
Date	Height (cm)	No. Shoots m^{-2}	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Height (m) Pr	Height (m) Nf	No. Shoots m^{-2} Pr	No. Shoots m^{-2} Nf	Dry Weight $g\ m^{-2}$ Pr	Dry Weight $g\ m^{-2}$ Nf	Ash-Free Dry Weight $g\ m^{-2}$ Pr	Ash-Free Dry Weight $g\ m^{-2}$ Nf	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Other[1] Species Present
6/17	6	476	68	48					3		2		71	50	Mt, Ec
		75	8	6					1		1		8	6	
7/7	6	434	63	46					1		1		64	47	
		46	8	5					0.5		0.4		7	5	
	3	138													
		41													
8/6	7	695	82	57					0.4	6	0.3	4	88	61	
		66	5	3						3		2	5	3	
	3	114													
		28													
9/2	6	752	86	61					1		1		87	62	Mt
		85	9	6					1		1		9	6	
	3	213													
		55													

1. Species designated as Pr = *Potamogeton robbinsii*, Nf = *Nitella flexilis*, Mt = *Myriophyllum tenellum*.

Table F4. Measurements from *Potamogeton robbinsii* bed on Lake George transect in 1981. Mean values given in the table. Where two entries are made in a column for a date, the second is 1 standard error; n = 10.

	Potamogeton robbinsii			Secondary Species[1]			Sample Totals		
Date	No. Shoots m^{-2}	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	No. Shoots m^{-2} Ir	Dry Weight $g\ m^{-2}$ Ir	Ash-Free Dry Weight $g\ m^{-2}$ Ir	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Notes
6/17		25	18		9	6	34	24	
		13	9		7	5	15	11	
7/7		2	2		5	3	7	5	
		1	1		3	2	3	2	
8/6		11	8		1	0.5	12	8	
		3	2		1	0.4	3	2	
9/2		17	13				17	13	
		4	3				4	3	

1. Species designated as Ir = *Isoetes riparia*.

Table B5. Measurements from inshore portion of *Scirpus americanus* bed on Lake Nicolet transect in 1981. Mean values given in the table. Where two entries are made in a column for a date, the second is 1 standard error; n = 10.

	Scirpus americanus				Mixed Species[1]				Sample Totals		
Date	Height (m)	No. Shoots m^{-2}	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Height (m)	No. Shoots m^{-2}	Dry Weight $g\ m^{-2}$	Ash-Free Dry Weight g m	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Other[1] Species Present
6/11	0.3	114	21	19			18	16	38	35	
		16	3	3			5	5	3	3	
7/10	0.7	130	82	79			105	99	187	178	
		25	19	18			18	17	21	20	
8/8	0.8	148	137	130			202	193	339	323	
		21	20	19			28	27	23	22	
9/1	0.8	214	158	152			194	185	352	337	
		38	23	33			31	30	18	17	

1. A variety of aquatic and semi-aquatic species in shallow water (less than 0.2 m) including sedges, rushes and grasses.

Table B6. Measurements from offshore portion of *Scirpus americanus* bed on Lake Nicolet transect in 1981. Mean values given in the table. Where two entries are made in a column for a date, the second is 1 standard error; n = 10.

	Scirpus americanus				Secondary Species[1]				Sample Totals		
Date	Height (m)	No. Shoots m^{-2}	Dry Wt. g m^{-2}	Ash-Free Dry Wt. g m^{-2}	Height (m) Es	No. Shoots m^{-2} Es	Dry Weight g m^{-2} Es	Ash-Free Dry Weight g m^{-2} Es	Dry Wt. g m^{-2}	Ash-Free Dry Wt. g m^{-2}	Other[1] Species Present
6/11	0.2	89	16	15	0.2	56	6	5	22	20	
		11	2	1			3	3	2	2	
7/10	0.8	160	88	83	0.4	7	1	1	89	84	
		20	9	8			1	1	8	8	
8/8	1.0	212	169	161	0.4	5	1	1	70	162	
		20	10	10			1	1	10	10	
9/1	1.0	305	285	272					285	272	
		21	11	10					11	10	

1. Species designated as Es = *Eleocharis smallii*.

Table B7. Measurements from charophyte bed on Lake Nicolet transect in 1981. Mean values given in the table. Where two entries are made for a date, the second is 1 standard error; n = 10.

	Nitella flexilis				Secondary Species[1]				Sample Totals	
Date	No. Shoots m^{-2}	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Mean % Composition by charophyte species	Dry Weight $g\ m^{-2}$ Ec	Dry Weight $g\ m^{-2}$ Pr	Ash-Free Dry Weight $g\ m^{-2}$ Ec	Ash-Free Dry Weight $g\ m^{-2}$ Pr	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$
6/17		26	18	Nf = 95%; Cg = 5%	2	7	5	2	35	25
		7	4						13	8
7/15		18	13	Nf = 99%; Cg = 1%					18	13
		6	4						6	4
8/10		58	24	Nf = 100%	1		0.5		58	25
		14	6		0.5		0.3		14	6
9/9		80	54	Nf = 100%	6		4		86	59
		13	6		1		1		12	6

1. Species designated as Nf = *Nitella flexilis*, Cg = *Chara globularis*, Ec = *Elodea canadensis*, Pr = *Potamogeton richardsonii*.

Table B8. Measurements from *Isoetes riparia* bed on Course 7 transect in 1981. Mean values given in the table. Where two entries are made in a column for a date, the second is 1 standard error; n = 10.

	Isoetes riparia				Secondary Species[1]								Sample Totals		
Date	Height (cm)	No. Shoots m^{-2}	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Height (m) Mt	Height (m) Ld	No. Shoots m^{-2} Mt	No. Shoots m^{-2} Ld	Dry Weight $g\ m^{-2}$ Mt	Dry Weight $g\ m^{-2}$ Ld	Ash-Free Dry Weight $g\ m^{-2}$ Mt	Ash-Free Dry Weight $g\ m^{-2}$ Ld	Dry Wt. $g\ m^{-2}$	Ash-Free Dry Wt. $g\ m^{-2}$	Other[1] Species Present
6/7	6	482 84	81 9	59 6					7 2	1	6 2	1	88 8	65 5	Ec
7/14	8	500	103 7	76 5					1 0.5		1 0.5		103 7	76 5	Ec
8/12	8	634 78	98 9	72 5					5 1		4 1		103 9	75 5	Ea
	3	26 13													
8/31	8	534 40	86 4	65 3					5 2		5 2		91 5	69 4	Ea
	3	40 12													

1. Species designated as Mt = *Myriophyllum tennellum*, Ld = *Lobelia dortmanna*, Ec = *Elodea canadensis*, Ea = *Eleocharis acicularis*.

Table B9. Measurements from charophyte bed on Course 7 transect in 1981. Where two entries are made in a column for a date, the second is 1 standard error; n = 10.

	Nitella flexilis				*Sample Totals*	
Date	No. Shoots m^{-2}	Dry Wt. g m^{-2}	Ash-Free Dry Wt. g m^{-2}		Dry Wt. g m^{-2}	Ash-Free Dry Wt. g m^{-2}
6/7		69	47	mean % composition by charophyte species:	69	47
		16	13	*Nitella flexilis* = 96%; *Tolypella intricata* = 4%	16	13
7/14		83	57	mean % composition by charophyte species:	83	57
		17	12	*Nitella flexilis* = 100%.	17	12
8/12		75	42	mean % composition by charophyte species:	75	42
		12	5	*Nitella flexilis* = 100%	12	5
8/31		87	57	mean % composition by charophyte species:	87	57
		10	4	*Nitella flexilis* = 100%	10	4

Table B10. Biomass of aquatic macrophytes taken on transects along the edge of the Upbound Neebish Channel on August 15, 1981.

River Course No.	Channel Marker Nos.[1]	Position[2]	Depth m	Species	Ash-Free[3] Dry Wt. g m^{-2}	Remarks
5	72-70	A	6.5	Nitella flexilis	61.52	Brown clay
		B	4.5	Nitella flexilis Tolypella intricata	19.52	Silty clay
		C	4.7	Nitella flexilis Tolypella intricata	55.83	Silty clay
		D	4.7	Chara globularis Nitella flexilis Tolypella intricata	21.09	Silty clay
		E	4.8	Chara globularis Nitella flexilis Tolypella intricata	21.55	Silty clay
	68-66	A	8.5	None		Sandy clay, few pebbles
		B	8.2	Nitella flexilis	2.19[4]	Silty clay, some pebbles
		C	5.3	Nitella flexilis Chara globularis	61.54	Sandy clay
		D	3.7	Nitella flexilis Chara globularis	21.99	Sandy clay
		E	3.8	Nitella flexilis Chara globularis	32.88	Silty clay, few rocks

River Course No.	Channel Marker Nos.	Position[2]	Depth m	Species	Ash-Free[3] Dry Wt, $g\ m^{-2}$	Remarks
7	38-36	A	8.8	None		Sandy clay
		B	8.0	None		Sandy clay, some rocks
		C	4.0	Nitella flexilis	81.73	Silty clay
		D	4.5	Nitella flexilis	104.95	Silty clay
		E	5.1	Nitella flexilis	58.68	Silty clay
	32-30	A	7.7	None		Silty clay, one rock
		B	7.5	None		Silty clay
		C	6.8	Nitella flexilis	0.34	Silty clay
		D	5.8	Nitella flexilis	94.34	Silty clay
		E	5.3	Nitella flexilis Elodea canadensis	33.26 1.78[4]	Silty clay Two plants, 15 cm each
5	16-14	A	7.9	None		Silty clay
		B	4.5	Nitella flexilis Elodea canadensis	33.10 0.19[4]	Silty clay
		C	3.8	Nitella flexilis Chara globularis	46.97	Silty clay
		D	3.8	Nitella flexilis	33.61	Silty clay, few rocks
		E	3.5	Nitella flexilis	21.81	Silty clay

River Course No.	Channel Marker Nos.	Position	Depth m	Species	Ash-Free[3] Dry Wt. $g\ m^{-2}$	Remarks
9	14-12	A	10.0	None		Brown clay
		B	6.9	None		Silty clay
		C	4.9	*Nitella flexilis* *Chara globularis*	60.43	Silty clay, few pebbles
		D	6.0	None		Silty clay
		E	4.8	*Nitella flexilis*	14.69	Silty clay

1. Transects located between markers indicated by number on navigation chart for Upbound Neebish Channel.
2. Position A was located in the starboard portion of the upbound channel; B. C. D. and E. were spaced along a line approximately 100 m long going progressively shoreward.
3. Ponar sampler used collected from 0.052 m^2.
4. Insufficient dry biomass was present in these samples (less than 0.08 g) to accurately estimate ash content; tabled values were obtained from the average ash content of the species in samples where sufficient material was present.

Appendix C. Collection records for each larval fish sampling date including station, gear type, time, volume filtered, and density of larvae, St. Marys River, 1981. (Total larval density for each sample may not equal the sum of densities for all species due to rounding of numbers.)

Table C1. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone of the St. Marys River, Station 5 and Lake George, 9 April, 1981.

	Station											
	5-P-1	5-P-2	5-P-3		5-P-1	5-P-2	5-P-3		LG-P-1	LG-P-2	LG-P-3	
Time (h)	1415	1425	1435	TOTAL	2044	2050	2100	TOTAL	1612	1618	1625	TOTAL
Volume filtered (m^3)	2.4	1.9	2.5	6.8	3.9	3.2	2.3	9.4	3.1	3.8	3.9	10.8
Larvae												
Lake whitefish	83.3	0	0	29.4	0	0	0	0	0	0	0	0
TOTAL	83.3	0	0	29.4	0	0	0	0	0	0	0	0

Table C2. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone of the St. Marys River, Stations 7 and 9, 10 April, 1981.

	Station							
	7-P-1	7-P-2	7-P-3		9-P-1	9-P-2	9-P-3	
Time (h)	1040	1050	1059	TOTAL	1000	1005	1010	TOTAL
Volume filtered (m^3)	3.4	3.9	4.1	11.4	3.7	3.9	3.8	11.4
Larvae	0	0	0	0	0	0	0	0

Table C3. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 9 April, 1980.

	Station											
	5-S-1	5-S-2		5-S-1	5-S-2		5-C-1	5-C-2		5-C-1	5-C-2	
Time (h)	1415	1425	TOTAL	N	N	TOTAL	1441	1503	TOTAL	2055	-	TOTAL
Volume filtered (m^3)	44.8	44.2	89.0	64.8	71.08	136.6	92.0	101.4	193.9	140.7	152.3	293.0
Larvae												
Lake whitefish	0	0	0	0	1	<1	0	0	0	0	0	0
TOTAL	0	0	0	0	1	<1	0	0	0	0	0	0

Table C4. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 10 April, 1980.

	Station					
	7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	D	D	TOTAL	1110	1130	TOTAL
Volume filtered (m^3)	63.4	66.0	129.4	147.7	154.3	302.0
Larvae						
Burbot	0	0	0	<1	0	0
TOTAL	0	0	0	<1	0	0

Table C5. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 10 April, 1980.

	Station					
	9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	D	D	TOTAL	1035	1050	TOTAL
Volume filtered (m^3)	76.1	70.5	146.6	158.2	155.5	313.7
Larvae						
Cisco	11	4	8	0	0	0
Burbot	29	3	16	1	2	2
TOTAL	39	7	24	1	2	2

Table C6. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 10 April, 1980.

	Station					
	LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	1636	1645	TOTAL	1610	-	TOTAL
Volume filtered (m^3)	46.4	46.0	92.4	88.3	93.4	181.7
Larvae	0	0	0	0	0	0

Table C7. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone of the St. Marys River, 13 April, 1981.

	Station											
	5-P-1	5-P-2	5-P-3		5-P-1	5-P-2	5-P-3		7-P-1	7-P-2	7-P-3	
Time (h)	0945	0950	1000	TOTAL	2045	2100	2110	TOTAL	D	D	D	TOTAL
Volume filtered (m^3)	2.6	3.9	3.5	10.0	3.3	3.2	4.4	10.9	3.5	3.4	3.7	10.6
Larvae												
Cisco	0	0	0	0	0	31	0	9	0	0	0	0
Lake whitefish	0	0	0	0	61	0	0	18	0	0	0	0
Burbot	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	61	31	0	28	0	0	0	0

	Station							
	9-P-1	9-P-2	9-P-3		LG-P-1	LG-P-2	LG-P-3	
Time (h)	1100	1105	1110	TOTAL	1235	D	D	TOTAL
Volume filtered (m^3)	3.9	3.7	4.2	11.8	4.4	3.7	4.3	12.4
Larvae								
Cisco	0	0	0	0	0	0	0	0
Lake whitefish	0	0	0	0	0	0	0	0
Burbot	26	0	24	17	0	0	0	0
TOTAL	26	0	24	17	0	0	0	0

Table C8. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 13 April, 1981.

	Station											
	5-S-1	5-S-2		5-S-1	5-S-2		5-C-1	5-C-2		5-C-1	5-C-2	
Time (h)	0945	1000	TOTAL	2045	2055	TOTAL	1020	1030	TOTAL	2020	2030	TOTAL
Volume filtered (m^3)	64.3	62.6	126.9	74.5	73.1	147.6	155.9	147.4	303.3	156.4	162.9	319.3
Larvae												
Cisco	0	0	0	0	3	1	0	0	0	0	<1	<1
Burbot	3	0	2	0	0	0	0	<1	<1	0	0	0
TOTAL	3	0	2	0	3	1	0	<1	<1	0	<1	<1

Table C9. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 13 April, 1981.

	Station					
	7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	1325	1335	TOTAL	1305	1315	TOTAL
Volume filtered (m^3)	67.0	66.2	133.2	144.1	133.0	277.1
Larvae						
Burbot	1	5	3	0	0	0
TOTAL	1	5	3	0	0	0

Table C10. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 13 April, 1981.

	Station					
	9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	1145	1200	TOTAL	1225	1235	TOTAL
Volume filtered (m^3)	66.0	69.5	135.5	133.6	131.4	265.0
Larvae						
Cisco	2	0	<1	0	0	0
Burbot	9	24	17	0	3	2
TOTAL	11	24	18	0	3	2

Table C11. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 13 April, 1981.

	Station					
	LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	1520	1530	TOTAL	1430	1500	TOTAL
Volume filtered (m^3)	69.9	70.9	140.8	137.8	148.2	286.0
Larvae						
Burbot	0	0	0	0	1	<1
TOTAL	0	0	0	0	1	<1

Table C12. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone of the St. Marys River, 17 April, 1981.

	Station											
	5-P-1	5-P-2	5-P-3		5-P-1	5-P-2	5-P-3		7-P-1	7-P-2	7-P-3	
Time (h)	1030	-	1055	TOTAL	2005	-	-	TOTAL	1305	-	1325	TOTAL
Volume filtered (m^3)	3.0	2.8	2.6	8.4	3.9	2.3	3.0	9.2	3.7	3.2	3.0	9.9
Larvae												
Cisco	67	0	0	24	0	43	0	11	27	0	0	10
Lake whitefish	0	36	0	12	51	0	33	33	0	63	0	20
Burbot	0	0	0	0	0	0	0	0	27	0	0	10
TOTAL	67	36	0	36	51	43	33	43	54	63	0	40

	Station							
	9-P-1	9-P-2	9-P-3		LG-P-1	LG-P-2	LG-P-3	
Time (h)	1205	-	1234	TOTAL	-	-	1450	TOTAL
Volume filtered (m^3)	2.4	2.6	3.8	8.8	3.7	3.9	4.3	11.9
Larvae								
Cisco	0	38	53	34	0	0	0	0
TOTAL	0	38	53	34	0	0	0	0

Table C13. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 17 April, 1981.

	Station											
	5-S-1	5-S-2		5-S-1	5-S-2		5-C-1	5-C-2		5-C-1	5-C-2	
Time (h)	1055	1105	TOTAL	2045	2045	TOTAL	1030	1040	TOTAL	2015	2015	TOTAL
Volume filtered (m^3)	70.5	73.2	143.7	53.3	56.5	109.8	151.8	150.6	302.4	152.1	155.8	307.9
Larvae												
Cisco	3	1	2	0	0	0	<1	0	<1	0	<1	<1
Burbot	0	0	0	0	0	0	1	0	<1	1	0	<1
TOTAL	3	1	2	0	0	0	2	0	<1	1	<1	<1

Table C14. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 17 April, 1981.

	Station					
	7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	1330	1340	TOTAL	1305	1315	TOTAL
Volume filtered (m^3)	72.7	70.5	143.2	147.2	149.0	296.2
Larvae						
Cisco	10	11	10	0	0	0
Burbot	0	26	13	5	2	3
TOTAL	10	37	23	5	2	3

Table C15. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 17 April, 1981.

	Station					
	9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	1230	1240	TOTAL	1200	-	TOTAL
Volume filtered (m^3)	78.3	73.7	152.0	151.0	151.7	302.7
Larvae						
Cisco	5	4	5	<1	<1	1
Lake whitefish	0	0	0	<1	0	<1
Burbot	5	4	5	17	13	15
TOTAL	10	8	9	19	14	16

Table C16. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 17 April, 1981.

	Station					
	LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	1435	1445	TOTAL	1410	1420	TOTAL
Volume filtered (m^3)	75.6	71.5	147.0	151.4	162.8	314.2
Larvae						
Cisco	0	0	0	<1	0	<1
TOTAL	0	0	0	<1	0	<1

Table C17. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone of the St. Marys River, 20 April, 1981.

	Station							
	5-P-1	5-P-2	5-P-3		5-P-1	5-P-2	5-P-3	
Time (h)	1010	1020	1030	TOTAL	2015	2025	2030	TOTAL
Volume filtered (m^3)	4.4	3.5	3.9	11.8	1.8	3.3	2.9	8.0
Larvae								
Cisco	0	0	0	0	56	0	103	50
Lake whitefish	114	114	128	119	167	333	172	238
TOTAL	114	114	128	119	222	333	276	288

Table C18. Density (No./100 m^3) of ichthyoplankton collected in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 20 April, 1981.

	Station											
	5-S-1	5-S-2		5-S-1	5-S-2		5-C-1	5-C-2		5-C-1	5-C-2	
Time (h)	1055	1055	TOTAL	2045	2045	TOTAL	1035	1035	TOTAL	2035	2035	TOTAL
Volume filtered (m^3)	51.5	49.8	101.3	52.9	55.0	107.9	113.9	107.8	221.7	178.1	172.1	350.2
Larvae												
Cisco	0	0	0	2	0	<1	0	0	0	<1	0	<1
Burbot	0	0	0	0	0	0	0	0	0	0	<1	<1
Fourhorn sculpin	0	0	0	0	0	0	0	0	0	<1	0	<1
TOTAL	0	0	0	2	0	<1	0	0	0	1	<1	<1

Table C19. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone and in 0.5 m net collections near macrophyte beds (S), Station 5, St. Marys River, 4 May, 1981.

	Station					
	5-P-1	5-P-2		5-S-1	5-S-2	
Time (h)	2215	-	TOTAL	2320	2320	TOTAL
Volume filtered (m^3)	1.4	1.0	2.4	52.2	46.6	98.8
Larvae						
Lake whitefish	0	0	0	0	6	3
Burbot	0	0	0	8	2	5
TOTAL	0	0	0	8	9	8

Table C20. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 5 May, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2237	-	TOTAL	2245	2245	TOTAL	2230	2230	TOTAL
Volume filtered (m^3)	8.4	4.2	12.6	50.1	51.9	102.0	76.8	76.8	153.6
Larvae									
Cisco	0	24	8	0	0	0	0	0	0
Lake whitefish	0	0	0	0	2	<1	0	0	0
Burbot	0	0	0	30	17	24	18	5	12
TOTAL	0	24	8	30	19	25	18	5	12

Table C21. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 5 May, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2122	-	TOTAL	2145	2145	TOTAL	2125	2125	TOTAL
Volume filtered (m^3)	3.9	4.0	7.9	57.9	58.6	116.5	72.0	72.0	144.0
Larvae									
Cisco	0	50	25	5	9	7	0	0	0
Lake whitefish	0	25	13	5	7	6	0	0	0
Burbot	0	0	0	7	10	9	29	22	26
Fourhorn sculpin	0	0	0	0	0	0	1	0	<1
TOTAL	0	75	38	17	26	21	31	22	26

Table C22. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, and in 0.5 m net collections near macrophyte beds (S), Lake George, St. Marys River, 4 May, 1981.

	Station					
	LG-P-1	LG-P-2		LG-S-1	LG-S-2	
Time (h)	2125	2132	TOTAL	2200	2200	TOTAL
Volume filtered (m^3)	7.7	4.7	12.4	47.7	46.7	94.4
Larvae	0	0	0	0	0	0

Table C23. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 14 May, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1	5-C-2	
Time (h)	0136	0141	TOTAL	0152	0159	TOTAL	0145	0145	TOTAL
Volume filtered (m^3)	1.8	2.5	4.3	48.0	48.7	96.7	105.4	97.9	203.3
Larvae									
Rainbow smelt	0	0	0	0	0	0	0	1	<1
Burbot	0	0	0	6	0	3	4	3	3
TOTAL	0	0	0	6	0	3	4	4	4

Table C24. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 14 May, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2305	2310	TOTAL	2321	2326	TOTAL	2325	2325	TOTAL
Volume filtered (m^3)	2.8	2.9	5.7	37.7	60.2	97.9	109.6	90.2	199.8
Larvae									
Cisco	0	0	0	0	2	1	0	0	0
Rainbow smelt	0	0	0	3	3	3	<1	0	<1
Burbot	0	0	0	3	15	10	3	4	4
TOTAL	0	0	0	5	20	14	4	4	4

Table C25. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P), in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 14 May, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2207	2212	TOTAL	2220	2229	TOTAL	2215	2215	TOTAL
Volume filtered (m^3)	2.8	2.9	5.7	44.0	51.3	95.3	91.2	102.4	193.6
Larvae									
Cisco	0	0	0	2	0	1	0	0	0
Lake whitefish	36	0	18	0	0	0	0	0	0
Rainbow smelt	0	0	0	9	0	4	0	2	1
Burbot	0	0	0	20	2	10	4	5	5
Yellow perch	0	0	0	11	0	5	0	0	0
Fourhorn sculpin	0	0	0	0	0	0	1	0	<1
TOTAL	36	0	18	43	2	21	5	7	6

Table C26. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P), in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 14 May, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	0005	0010	TOTAL	0020	0030	TOTAL	0040	0040	TOTAL
Volume filtered (m^3)	3.2	3.5	6.7	39.8	44.4	84.2	125.6	111.8	237.4
Larvae									
Rainbow smelt	0	0	0	63	5	32	18	24	21
Burbot	0	0	0	3	5	4	2	0	1
Yellow perch	0	0	0	0	0	0	<1	0	<1
TOTAL	0	0	0	65	9	36	21	24	22

Table C27. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 21* and 26 May, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1*	5-C-2*	
Time (h)	0030	0035	TOTAL	0045	0054	TOTAL	0100	-	TOTAL
Volume filtered (m^3)	1.8	2.2	4.0	68.5	62.3	130.8	106.7	94.6	201.3
Larvae									
Rainbow smelt	0	0	0	4	5	5	3	2	2
Burbot	0	0	0	7	2	5	2	7	4
Yellow perch	166	45	100	0	0	0	0	0	0
Fourhorn sculpin	0	0	0	0	0	0	0	1	<1
TOTAL	166	45	100	12	6	9	5	11	7

Table C28. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 21* and 26 May, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1*	7-C-2*	
Time (h)	2330	2335	TOTAL	2350	2357	TOTAL	2220	-	TOTAL
Volume filtered (m^3)	3.8	4.3	8.1	65.6	65.2	130.8	101.2	211.7	312.9
Larvae									
Rainbow smelt	0	0	0	9	9	9	2	<1	1
Burbot	0	0	0	5	5	5	5	2	3
TOTAL	0	0	0	14	14	14	7	3	4

Table C29. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 21* and 26 May, 1981.

	Station						
	9-P-1	9-P-2		9-S-1	9-C-1*	9-C-2*	
Time (h)	2205	2209	TOTAL	2231	2140	-	TOTAL
Volume filtered (m^3)	3.5	4.4	7.9	95.9	113.7	96.6	210.3
Larvae							
Rainbow smelt	0	0	0	0	3	1	2
Burbot	0	0	0	1	18	14	16
TOTAL	0	0	0	1	20	16	18

Table C30. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S) and in 1.0 m net collections in the channel, Lake George, St. Marys River, 21* and 26 May, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1*	LG-C-2*	
Time (h)	2220	2230	TOTAL	2240	2250	TOTAL	2350	-	TOTAL
Volume filtered (m^3)	3.6	3.7	7.3	69.4	64.8	134.2	115.7	114.2	229.9
Larvae									
Cisco	0	0	0	0	0	0	<1	0	<1
Rainbow smelt	0	0	0	35	34	34	58	60	59
Burbot	0	0	0	3	0	1	3	7	5
Yellow perch	250	459	342	10	3	7	0	<1	<1
TOTAL	250	459	342	48	37	42	62	67	65

Table C31. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 9 June, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1	5-C-2	
Time (h)	2245	2255	TOTAL	2215	2225	TOTAL	2230	-	TOTAL
Volume filtered (m^3)	1.9	3.0	4.9	44.1	54.3	98.4	110.5	114.7	225.2
Larvae									
Rainbow smelt	158	100	122	109	98	103	98	78	87
Burbot	0	0	0	0	2	1	<1	3	2
Yellow perch	1316	1533	1448	23	13	17	<1	0	<1
TOTAL	1474	1633	1571	132	112	121	100	79	89

Table C32. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 9 June, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2337	2341	TOTAL	2320	2330	TOTAL	2308	2325	TOTAL
Volume filtered (m^3)	3.9	4.2	8.1	27.8	79.2	107.0	113.8	85.5	199.3
Larvae									
Rainbow smelt	0	0	0	421	254	297	339	310	327
Burbot	0	0	0	18	3	7	2	2	2
TOTAL	0	0	0	439	256	304	341	312	329

Table C33. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 9 June, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2238	2244	TOTAL	2219	2230	TOTAL	2235	2250	TOTAL
Volume filtered (m^3)	3.1	3.5	6.6	63.4	71.4	134.8	98.1	105.5	203.6
Larvae									
Cisco	0	0	0	0	1	<1	0	0	0
Rainbow smelt	129	200	167	1498	1585	1545	338	267	302
Burbot	0	29	15	6	21	14	3	2	2
Cyprinidae	0	0	0	0	0	0	1	0	<1
Yellow perch	0	29	15	0	0	0	0	0	0
Fourhorn sculpin	0	0	0	0	0	0	1	0	<1
TOTAL	129	257	197	1505	1608	1559	344	269	305

Table C34. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 9 June, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	0035	0039	TOTAL	-	-	TOTAL	2352	0003	TOTAL
Volume filtered (m^3)	3.3	2.5	5.8	62.8	56.4	119.2	92.5	82.6	175.1
Larvae									
Rainbow smelt	0	0	0	24	48	35	206	190	199
Burbot	0	0	0	0	0	0	2	0	1
Cyprinidae	30	40	69	0	4	2	0	0	0
White sucker	91	40	34	0	0	0	0	0	0
Yellow perch	303	40	190	6	2	4	0	0	0
Logperch	30	40	34	0	0	0	0	0	0
Unidentifiable	0	0	0	2	0	<1	0	0	0
TOTAL	455	160	328	32	53	42	209	190	200

Table C35. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 23 June, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1	5-C-2	
Time (h)	0224	0235	TOTAL	0249	0258	TOTAL	0203	0212	TOTAL
Volume filtered (m^3)	4.5	2.7	7.2	61.9	52.2	114.1	122.0	107.4	229.4
Larvae									
Cisco	0	0	0	0	0	0	<1	0	<1
Rainbow smelt	0	0	0	0	2	<1	12	6	9
Central mudminnow	0	0	0	0	2	<1	0	0	0
White sucker	111	74	97	0	0	0	0	0	0
Burbot	0	0	0	0	0	0	<1	3	2
Lepomis sp.	0	0	0	0	2	<1	0	0	0
Johnny darter	0	0	0	2	2	2	0	0	0
Yellow perch	22	111	56	31	42	37	0	0	0
Logperch	0	0	0	0	0	0	<1	0	<1
Percidae	0	0	0	2	0	<1	0	0	0
TOTAL	133	185	153	34	52	42	15	8	12

Table C36. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 23 June, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2331	2340	TOTAL	2345	2355	TOTAL	2328	2340	TOTAL
Volume filtered (m^3)	4.6	4.9	9.5	64.0	61.8	125.8	104.7	104.2	208.9
Larvae									
Rainbow smelt	0	0	0	3	0	2	5	6	5
Central mudminnow	0	0	0	0	2	<1	0	0	0
Burbot	0	0	0	0	2	<1	<1	2	1
Yellow perch	43	41	42	3	2	2	0	0	0
Percidae	0	0	0	0	2	<1	0	0	0
TOTAL	43	41	42	6	6	6	6	8	7

Table C37. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 23 June, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2221	2230	TOTAL	2253	2303	TOTAL	2220	2228	TOTAL
Volume filtered (m^3)	3.7	3.5	7.2	60.1	63.9	124.0	123.1	108.5	231.6
Larvae									
Rainbow smelt	0	0	0	0	0	0	11	8	9
Cyprinidae	0	0	0	2	0	<1	0	0	0
Burbot	0	0	0	0	0	0	2	6	4
Yellow perch	27	29	28	10	3	6	0	<1	<1
Percidae	0	57	28	0	0	0	0	0	0
TOTAL	27	86	56	12	3	7	13	15	14

Table C38. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 23 June, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	0037	0049	TOTAL	0109	0125	TOTAL	0041	0051	TOTAL
Volume filtered (m^3)	3.1	3.6	6.7	51.0	52.5	103.5	90.7	115.2	205.9
Larvae									
Rainbow smelt	0	0	0	10	0	5	17	8	12
Carp	0	0	0	2	0	<1	0	0	0
Cyprinidae	226	28	119	2	11	7	0	0	0
Ninespine stickleback	0	0	0	0	0	0	1	0	<1
Johnny darter	65	28	45	0	2	<1	0	<1	<1
Yellow perch	65	28	45	2	6	4	0	0	0
Logperch	97	333	224	2	38	20	1	2	1
Percidae	32	0	15	0	0	0	0	0	0
TOTAL	484	417	447	18	57	38	19	10	14

Table C39. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 7 July, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1	5-C-2	
Time (h)	0151	0157	TOTAL	0206	0214	TOTAL	0157	0207	TOTAL
Volume filtered (m^3)	2.3	2.3	4.6	60.3	50.8	111.1	119.3	125.4	244.7
Larvae									
Rainbow smelt	0	0	0	2	2	2	7	3	5
Carp	1086	1130	1109	53	132	89	0	0	0
Cyprinidae	43	87	65	5	12	8	0	0	0
Trout-perch	0	43	22	2	2	2	0	0	0
Johnny darter	43	0	22	3	4	4	0	0	0
Yellow perch	391	435	413	28	28	28	<1	<1	<1
Logperch	0	478	239	7	41	23	0	0	0
Percidae	87	1000	543	3	20	11	0	0	0
TOTAL	1652	3174	2413	103	240	166	8	4	6

Table C40. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 7 July, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2326	2330	TOTAL	2341	2350	TOTAL	2353	0003	TOTAL
Volume filtered (m^3)	2.4	1.7	4.1	51.3	48.3	99.6	114.3	117.9	232.2
Larvae									
Rainbow smelt	0	0	0	2	0	1	2	5	3
Cyprinidae	0	0	0	0	2	1	0	0	0
Catostomidae	42	0	24	2	0	1	0	0	0
Trout-perch	0	0	0	0	2	1	0	<1	<1
Ninespine stickleback	0	0	0	2	4	3	0	0	0
Johnny darter	125	0	73	0	4	4	0	0	0
Yellow perch	42	0	24	29	0	15	0	3	2
Logperch	0	0	0	0	6	3	2	0	<1
Percidae	125	59	98	0	0	0	0	0	0
Cottus sp.	42	0	24	12	12	12	<1	0	<1
TOTAL	375	59	244	47	31	39	4	9	7

Table C41. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 7 July, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	0019	0025	TOTAL	0038	0049	TOTAL	0038	0054	TOTAL
Volume filtered (m^3)	2.6	1.3	3.9	50.7	48.7	99.4	116.1	120.2	236.3
Larvae									
Rainbow smelt	0	0	0	2	0	1	0	2	<1
Carp	0	0	0	2	0	1	0	0	0
Catostomidae	3115	4462	3564	65	43	54	167	133	150
Trout-perch	0	0	0	0	4	2	4	4	4
Ninespine stickleback	0	0	0	0	0	0	2	0	<1
Johnny darter	115	0	77	8	21	14	10	2	6
Yellow perch	346	154	282	0	0	0	0	<1	<1
Logperch	77	0	51	43	16	30	15	7	11
Percidae	346	846	513	2	2	2	0	0	0
Cottus sp.	0	0	0	6	10	8	29	13	21
TOTAL	4000	5462	4487	128	97	113	227	163	195

Table C42. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 7 July, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	2223	2229	TOTAL	2240	2249	TOTAL	2245	2257	TOTAL
Volume filtered (m^3)	2.0	2.0	4.0	52.1	48.5	100.6	102.7	104.1	206.8
Larvae									
Cisco	0	0	0	0	0	0	0	<1	6
Rainbow smelt	0	0	0	0	0	0	5	8	<1
Carp	0	0	0	10	14	12	2	3	2
Cyprinidae	450	200	325	111	33	74	<1	0	<1
Catostomidae	50	0	25	0	0	0	0	0	0
Ninespine stickleback	0	0	0	0	0	0	0	<1	<1
Rock bass	0	50	25	6	2	4	0	0	0
Johnny darter	0	0	0	17	12	15	<1	2	1
Yellow perch	50	100	75	0	0	0	<1	0	<1
Logperch	0	100	50	29	8	19	0	<1	<1
Percidae	150	50	100	2	0	<1	0	0	0
Cottus sp.	0	0	0	0	0	0	2	<1	1
TOTAL	700	500	600	175	70	124	12	16	14

Table C43. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 20 July, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1	5-C-2	
Time (h)	2332	2335	TOTAL	2349	2349	TOTAL	2330	2340	TOTAL
Volume filtered (m^3)	3.2	3.4	6.6	41.2	40.8	82.0	125.0	99.0	224.0
Larvae									
Rainbow smelt	0	0	0	0	2	1	12	17	14
Carp	63	0	30	7	12	10	0	0	0
Cyprinidae	0	206	106	46	10	28	<1	0	<1
Catostomidae	63	0	30	0	0	0	0	0	0
Trout-perch	0	0	0	0	5	2	0	0	0
Johnny darter	0	29	15	2	2	2	0	0	0
Logperch	125	59	91	5	0	2	0	0	0
Percidae	250	441	348	2	2	2	0	<1	<1
Cottus sp.	0	0	0	0	0	0	2	0	<1
TOTAL	500	735	621	63	34	49	14	18	16

Table C44. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 20 July, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2244	2248	TOTAL	2258	2258	TOTAL	2245	-	TOTAL
Volume filtered (m^3)	3.3	2.4	5.7	49.9	47.9	97.8	116.4	123.4	239.8
Larvae									
Alewife	0	0	0	0	0	0	0	<1	<1
Rainbow smelt	30	0	18	0	6	3	9	6	8
Cyprinidae	182	0	105	6	4	5	<1	<1	<1
Catostomidae	394	42	245	0	0	0	0	0	0
Trout-perch	30	0	18	2	0	1	0	<1	<1
Johnny darter	0	0	0	4	4	4	<1	0	<1
Logperch	61	167	105	0	0	0	3	4	3
Percidae	757	500	649	12	2	7	0	0	0
TOTAL	1454	708	1140	24	17	20	13	13	13

Table C45. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 20 July, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2152	2201	TOTAL	2215	2215	TOTAL	2140	2150	TOTAL
Volume filtered (m^3)	2.6	2.1	4.7	43.5	45.0	88.5	93.5	110.6	204.1
Larvae									
Alewife	0	0	0	2	2	2	3	2	2
Rainbow smelt	0	0	0	11	4	8	0	<1	<1
Cyprinidae	115	95	106	25	4	15	2	<1	1
Catostomidae	192	619	383	0	2	1	0	0	0
Johnny darter	308	1190	702	2	0	1	0	0	0
Yellow perch	0	0	0	9	0	5	0	0	0
Logperch	346	1238	744	57	58	58	0	2	<1
Percidae	77	476	255	0	0	0	0	0	0
TOTAL	1038	3619	2191	108	71	89	5	5	5

Table C46. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 21 July, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	-	2205	TOTAL	2218	2218	TOTAL	2248	2258	TOTAL
Volume filtered (m^3)	2.8	2.8	5.6	44.7	44.7	89.4	111.3	111.3	222.6
Larvae									
Alewife	0	0	0	2	13	8	28	24	26
Rainbow smelt	0	0	0	0	2	1	3	2	2
Carp	0	0	0	2	0	1	16	4	10
Cyprinidae	1214	2393	1804	72	36	54	5	6	6
Catostomidae	285	0	143	0	0	0	0	0	0
Trout-perch	0	0	0	0	0	0	0	<1	<1
Ninespine stickleback	0	0	0	0	0	0	4	<1	3
Lepomis sp.	107	71	89	0	0	0	0	0	0
Johnny darter	0	0	0	0	0	0	4	3	3
Logperch	714	607	661	0	0	0	2	<1	1
Percidae	321	107	214	2	0	1	0	0	0
Cottus sp.	0	0	0	0	0	0	<1	0	<1
TOTAL	2643	3179	2911	76	51	65	63	41	52

Table C47. Density (No/100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 4 August, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1	5-C-2	
Time (h)	0022	0027	TOTAL	0038	0038	TOTAL	0025	0035	TOTAL
Volume filtered (m^3)	3.0	2.9	5.9	47.7	44.9	92.6	120.3	109.7	230.0
Larvae									
Alewife	0	0	0	0	0	0	0	<1	<1
Rainbow smelt	0	0	0	0	0	0	2	0	<1
Cyprinidae	33	34	34	90	49	70	0	0	0
Trout-perch	0	34	17	0	0	0	0	<1	<1
Ninespine stickleback	0	0	0	0	0	0	0	<1	<1
Yellow perch	0	0	0	0	2	1	0	0	0
Logperch	100	138	119	2	0	1	0	<1	<1
Percidae	200	690	441	2	0	1	0	0	0
TOTAL	333	862	593	94	51	73	2	4	3

Table C48. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 4 August, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2230	2238	TOTAL	2246	2246	TOTAL	2245	2250	TOTAL
Volume filtered (m^3)	4.4	3.5	7.9	53.2	50.1	103.3	115.5	125.3	240.8
Larvae									
Alewife	0	0	0	0	4	2	0	<1	<1
Rainbow smelt	0	57	25	0	2	2	3	<1	2
Cyprinidae	1250	543	937	0	6	3	0	0	0
Logperch	45	29	38	2	0	<1	0	0	0
Percidae	977	829	911	0	0	0	0	0	0
TOTAL	2273	1457	1911	2	12	7	3	2	2

Table C49. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 4 August, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2149	2153	TOTAL	2205	2205	TOTAL	2135	2145	TOTAL
Volume filtered (m^3)	2.3	3.1	5.4	49.6	52.8	102.4	96.7	146.5	243.2
Larvae									
Alewife	0	0	0	0	0	0	0	1	<1
Rainbow smelt	0	0	0	18	28	23	0	<1	<1
Carp	0	32	19	0	0	0	0	0	0
Cyprinidae	43	226	148	0	0	0	0	0	0
Yellow perch	0	0	0	0	4	2	0	0	0
Logperch	43	774	463	0	4	2	0	0	0
Percidae	348	935	685	0	0	0	0	0	0
TOTAL	435	1968	1315	18	36	27	0	2	1

Table C50. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 4 August, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	2322	2326	TOTAL	2339	2339	TOTAL	2330	2345	TOTAL
Volume filtered (m^3)	2.4	2.7	5.1	51.5	48.7	100.2	120.2	127.8	248.0
Larvae									
Alewife	0	0	0	0	0	0	5	7	6
Rainbow smelt	0	0	0	2	0	<1	0	0	0
Carp	0	0	0	0	0	0	3	2	2
Cyprinidae	3917	4667	4314	95	103	99	0	2	1
Trout-perch	0	0	0	0	0	0	2	0	1
Ninespine stickleback	0	0	0	0	0	0	0	<1	<1
Johnny darter	0	0	0	0	0	0	2	3	2
Yellow perch	0	37	20	0	0	0	0	0	0
Logperch	42	0	20	0	0	0	0	0	0
Percidae	208	222	216	0	0	0	2	0	<1
TOTAL	4167	4926	4569	97	103	100	14	15	15

Table C51. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 24 August, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1	5-C-2	
Time (h)	0015	0020	TOTAL	0035	0035	TOTAL	0020	-	TOTAL
Volume filtered (m^3)	4.5	3.5	8.0	54.6	52.7	107.3	113.2	93.0	206.2
Larvae									
Rainbow smelt	0	29	13	0	0	0	<1	0	<1
Cyprinidae	44	0	25	0	0	0	0	0	0
Logperch	111	0	63	0	0	0	0	0	0
Percidae	0	57	25	0	0	0	0	0	0
TOTAL	156	86	125	0	0	0	<1	0	<1

Table C52. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 24 August, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2210	2215	TOTAL	2210	2215	TOTAL	2205	2215	TOTAL
Volume filtered (m^3)	3.3	2.6	5.9	50.0	50.0	100.0	100.4	102.5	202.9
Larvae									
Rainbow smelt	0	0	0	0	0	0	<1	0	<1
Cyprinidae	30	38	34	0	0	0	0	0	0
Percidae	1152	385	814	0	0	0	0	0	0
TOTAL	1182	423	847	0	0	0	<1	0	<1

Table C53. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 24 August, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2120	2125	TOTAL	2137	2137	TOTAL	2120	-	TOTAL
Volume filtered (m^3)	4.3	4.1	8.4	50.0	50.5	100.5	139.8	111.5	251.3
Larvae									
Rainbow smelt	0	0	0	6	4	5	0	0	0
Cyprinidae	47	0	24	0	0	0	0	0	0
Logperch	0	0	0	2	0	<1	0	0	0
Percidae	23	46	238	0	0	0	0	0	0
TOTAL	70	46	262	8	4	6	0	0	0

Table C54. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 24 August, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	2300	2305	TOTAL	2320	2320	TOTAL	2300	2315	TOTAL
Volume filtered (m^3)	3.5	3.4	6.9	44.1	42.5	86.6	109.0	118.6	227.6
Larvae									
Alewife	0	0	0	0	0	0	0	<1	<1
Rainbow smelt	0	0	0	0	0	0	0	<1	<1
Cyprinidae	571	941	754	0	0	0	0	0	0
Percidae	29	0	14	0	0	0	0	0	0
TOTAL	600	941	768	0	0	0	0	2	<1

Table C55. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 10 September, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1	5-C-2	
Time (h)	2245	2255	TOTAL	2310	2310	TOTAL	2245	2305	TOTAL
Volume filtered (m^3)	4.1	3.6	7.7	46.3	44.0	90.3	113.7	119.3	233.0
Larvae	0	0	0	0	0	0	0	0	0

Table C56. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 10 September, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2100	2110	TOTAL	2120	2120	TOTAL	2110	2120	TOTAL
Volume filtered (m^3)	3.6	4.1	7.7	43.9	41.4	85.3	108.3	121.5	229.8
Larvae	0	0	0	0	0	0	0	0	0

Table C57. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 10 September, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2040	-	TOTAL	2030	2030	TOTAL	2000	2040	TOTAL
Volume filtered (m^3)	3.6	3.8	7.4	41.7	43.3	85.0	121.6	116.7	238.3
Larvae	0	0	0	0	0	0	0	0	0

Table C58. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 10 September, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	2200	2210	TOTAL	2220	2220	TOTAL	2200	2210	TOTAL
Volume filtered (m^3)	2.6	3.9	6.5	48.0	45.0	93.0	129.2	118.3	247.5
Larvae	0	0	0	0	0	0	0	0	0

Table C59. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 5, St. Marys River, 28 September, 1981.

	Station								
	5-P-1	5-P-2		5-S-1	5-S-2		5-C-1	5-C-2	
Time (h)	2240	2250	TOTAL	2305	2305	TOTAL	2240	2250	TOTAL
Volume filtered (m^3)	3.5	3.4	6.9	50.3	49.3	99.6	137.0	124.7	261.7
Larvae	0	0	0	0	0	0	0	0	0

Table C60. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 7, St. Marys River, 28 September, 1981.

	Station								
	7-P-1	7-P-2		7-S-1	7-S-2		7-C-1	7-C-2	
Time (h)	2040	2055	TOTAL	2110	2110	TOTAL	2045	2055	TOTAL
Volume filtered (m^3)	3.5	3.2	6.7	51.4	50.3	101.7	125.5	120.9	246.4
Larvae	0	0	0	0	0	0	0	0	0

Table C61. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the navigation channel (C), Station 9, St. Marys River, 28 September, 1981.

	Station								
	9-P-1	9-P-2		9-S-1	9-S-2		9-C-1	9-C-2	
Time (h)	2000	2010	TOTAL	2025	2025	TOTAL	2000	2010	TOTAL
Volume filtered (m^3)	3.5	3.6	7.1	47.1	45.6	92.7	139.4	132.8	272.2
Larvae	0	0	0	0	0	0	0	0	0

Table C62. Density (No./100 m^3) of ichthyoplankton collected in pull net collections (P) in the littoral zone, in 0.5 m net collections near macrophyte beds (S), and in 1.0 m net collections in the channel (C), Lake George, St. Marys River, 28 September, 1981.

	Station								
	LG-P-1	LG-P-2		LG-S-1	LG-S-2		LG-C-1	LG-C-2	
Time (h)	2140	2150	TOTAL	2205	2205	TOTAL	2140	2150	TOTAL
Volume filtered (m^3)	3.1	3.3	6.4	45.8	43.8	89.6	117.3	112.7	230.0
Larvae									
Alewife	0	0	0	0	0	0	<1	<1	<1
TOTAL	0	0	0	0	0	0	<1	<1	<1

APPENDIX D. Spatial and temporal occurrences of larval fish (no./100 m^3) collected in the St. Marys River, 1981. (Refer to Table 6 in text for dates of week 1, week 2, etc.)

Table D1. Spatial and temporal occurrence of rainbow smelt larvae (No./100 m^3) collected in the St. Marys River, 1981.

Location/Gear	Week 1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	0	122	0	0	0	0	13	0	0
0.5 m net	0	0	0	0	0	0	5	103	<1	2	1	0	0	0	0
1.0 m net	0	0	0	0	-	<1	2	87	9	5	14	<1	<1	0	0
Station 7															
Pull net	0	0	0	-	0	0	0	0	0	0	18	25	0	0	0
0.5 m net	0	0	0	-	0	3	9	297	2	1	3	2	0	0	0
1.0 m net	0	0	0	-	0	<1	1	327	5	3	8	2	<1	0	0
Station 9															
Pull net	0	0	0	-	0	0	0	167	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	4	0	1545	0	1	8	23	5	0	0
1.0 m net	0	0	0	-	0	1	2	302	9	<1	<1	<1	0	0	0
Lake George															
Pull net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	32	34	35	5	0	1	<1	0	0	0
1.0 m net	0	0	0	-	0	21	59	199	12	<1	2	0	<1	0	0

Table D2. Spatial and temporal occurrence of cyprinid larvae (No./100 m^3) collected in the St. Marys River, 1981.

	Week														
Location/Gear	1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	0	0	0	65	106	34	25	0	0
0.5 m net	0	0	0	0	0	0	0	0	0	8	28	70	0	0	0
1.0 m net	0	0	0	0	-	0	0	0	0	0	<1	0	0	0	0
Station 7															
Pull net	0	0	0	0	0	0	0	0	0	0	105	937	34	0	0
0.5 m net	0	0	0	0	0	0	0	0	0	1	5	3	0	0	0
1.0 m net	0	0	0	0	0	0	0	0	0	0	<1	0	0	0	0
Station 9															
Pull net	0	0	0	0	0	0	0	0	0	0	106	148	24	0	0
0.5 m net	0	0	0	0	0	0	0	0	<1	0	15	0	0	0	0
1.0 m net	0	0	0	0	0	0	0	<1	0	0	1	0	0	0	0
Lake George															
Pull net	0	0	0	0	0	0	0	69	119	325	1804	4314	754	0	0
0.5 m net	0	0	0	0	0	0	0	2	7	74	54	99	0	0	0
1.0 m net	0	0	0	0	0	0	0	0	0	<1	6	1	0	0	0

Table D3. Spatial and temporal occurrence of catostomid larvae (No./100 m^3) collected in the St. Marys River, 1981.

	Week														
Location/Gear	1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0
0.5 m net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0
Station 7															
Pull net	0	0	0	-	0	0	0	0	0	24	245	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	1	0	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
Station 9															
Pull net	0	0	0	-	0	0	0	0	0	3,564	383	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	54	1	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	150	0	0	0	0	0
Lake George															
Pull net	0	0	0	-	0	0	0	0	0	25	143	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0

Table D4. Spatial and temporal occurrence of burbot larvae (No./100 m^3) collected in the St. Marys River, 1981.

	Week														
Location/Gear	1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	2	0	0	5	3	5	1	0	0	0	0	0	0	0
1.0 m net	0	<1	<1	<1	-	3	4	2	2	0	0	0	0	0	0
Station 7															
Pull net	0	0	10	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	3	13	-	24	10	5	7	<1	0	0	0	0	0	0
1.0 m net	<1	0	3	-	12	4	3	2	1	0	0	0	0	0	0
Station 9															
Pull net	0	17	0	-	0	0	0	15	0	0	0	0	0	0	0
0.5 m net	16	17	5	-	9	10	1	14	0	0	0	0	0	0	0
1.0 m net	2	2	15	-	26	5	16	2	4	0	0	0	0	0	0
Lake George															
Pull net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	4	1	0	0	0	0	0	0	0	0
1.0 m net	0	<1	0	-	0	1	5	1	0	0	0	0	0	0	0

Table D5. Spatial and temporal occurrence of *Lepomis* sp. larvae (No./100 m^3) collected in the St. Marys River, 1981.

Location/Gear	Week 1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	0	0	0	543	348	441	25	0	0
0.5 m net	0	0	0	0	0	0	0	0	<1	11	2	1	0	0	0
1.0 m net	0	0	0	0	-	0	0	0	0	0	<1	0	0	0	0
Station 7															
Pull net	0	0	0	-	0	0	0	0	0	98	649	911	847	0	0
0.5 m net	0	0	0	-	0	0	0	0	<1	0	7	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	0	<1	0	0
Station 9															
Pull net	0	0	0	-	0	0	0	0	28	513	255	685	238	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	2	0	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
Lake George															
Pull net	0	0	0	-	0	0	0	0	15	100	214	216	14	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	<1	1	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	<1	0	0	0

Table D6. Spatial and temporal occurrence of logperch larvae (No./100 m^3) collected in the St. Marys River, 1981.

	Week														
Location/Gear	1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	0	0	0	239	91	119	63	0	0
0.5 m net	0	0	0	0	0	0	0	0	0	23	2	1	0	0	0
1.0 m net	0	0	0	0	–	0	0	0	<1	0	0	<1	0	0	0
Station 7															
Pull net	0	0	0	–	0	0	0	0	0	0	105	38	0	0	0
0.5 m net	0	0	0	–	0	0	0	0	0	3	0	<1	0	0	0
1.0 m net	0	0	0	–	0	0	0	0	0	<1	3	0	0	0	0
Station 9															
Pull net	0	0	0	–	0	0	0	0	0	51	744	463	0	0	0
0.5 m net	0	0	0	–	0	0	0	0	0	30	58	2	<1	0	0
1.0 m net	0	0	0	–	0	0	0	0	0	11	<1	0	0	0	0
Lake George															
Pull net	0	0	0	–	0	0	0	34	224	50	661	20	0	0	0
0.5 m net	0	0	0	–	0	0	0	0	20	19	0	0	0	0	0
1.0 m net	0	0	0	–	0	0	0	0	1	<1	1	0	0	0	0

Table D7. Spatial and temporal occurrence of yellow perch larvae (No./100 m^3) collected in the St. Marys River, 1981.

	Week														
Location/Gear	1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	100	1448	56	413	0	0	0	0	0
0.5 m net	0	0	0	0	0	0	0	17	37	28	0	1	0	0	0
1.0 m net	0	0	0	0	-	0	0	<1	0	<1	0	0	0	0	0
Station 7															
Pull net	0	0	0	-	0	0	0	0	42	24	0	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	2	15	0	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	2	0	0	0	0	0
Station 9															
Pull net	0	0	0	-	0	0	0	15	28	282	0	0	0	0	0
0.5 m net	0	0	0	-	0	5	0	0	6	0	5	2	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	<1	<1	0	0	0	0	0
Lake George															
Pull net	0	0	0	-	0	0	342	190	45	75	0	20	0	0	0
0.5 m net	0	0	0	-	0	0	7	4	4	0	0	0	0	0	0
1.0 m net	0	0	0	-	0	<1	<1	0	0	<1	0	0	0	0	0

Table D8. Spatial and temporal occurrence of johnny darter larvae (No./100 m^3) collected in the St. Marys River, 1981.

	Week														
Location/Gear	1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	0	0	0	22	15	0	0	0	0
0.5 m net	0	0	0	0	0	0	0	0	2	4	2	0	0	0	0
1.0 m net	0	0	0	0	–	0	0	0	0	0	0	0	0	0	0
Station 7															
Pull net	0	0	0	–	0	0	0	0	0	73	0	0	0	0	0
0.5 m net	0	0	0	–	0	0	0	0	0	4	4	0	0	0	0
1.0 m net	0	0	0	–	0	0	0	0	0	0	<1	0	0	0	0
Station 9															
Pull net	0	0	0	–	0	0	0	0	0	77	702	0	0	0	0
0.5 m net	0	0	0	–	0	0	0	0	0	14	1	0	0	0	0
1.0 m net	0	0	0	–	0	0	0	0	0	6	0	0	0	0	0
Lake George															
Pull net	0	0	0	–	0	0	0	0	45	0	0	0	0	0	0
0.5 m net	0	0	0	–	0	0	0	0	<1	15	0	0	0	0	0
1.0 m net	0	0	0	–	0	0	0	0	<1	1	3	2	0	0	0

Table D9. Spatial and temporal occurrence of carp larvae (No./100 m^3) collected in the St. Marys River, 1981.

	Week														
Location/Gear	1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	0	0	0	1,109	30	0	0	0	0
0.5 m net	0	0	0	0	0	0	0	0	0	89	10	0	0	0	0
1.0 m net	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0
Station 7															
Pull net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
Station 9															
Pull net	0	0	0	-	0	0	0	0	0	0	0	19	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	1	0	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
Lake George															
Pull net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	<1	12	1	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	2	10	2	0	0	0

Table D10. Spatial and temporal occurrence of alewife larvae (No./100 m^3) collected in the St. Marys River, 1981.

	Week														
Location/Gear	1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	0	0	-	0	0	0	0	0	0	<1	0	0	0
Station 7															
Pull net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	0	0	2	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	<1	<1	0	0	0
Station 9															
Pull net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	0	2	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	2	<1	0	0	0
Lake George															
Pull net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	0	8	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	26	6	<1	0	0

Table D11. Spatial and temporal occurrence of cisco larvae (No./100 m^3) collected in the St. Marys River, 1981.

	Week														
Location/Gear	1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	0	5	17	20	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	<1	1	<1	0	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	<1	<1	<1	-	0	0	0	<1	0	0	0	0	0	0
Station 7															
Pull net	0	0	10	-	8	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	10	-	0	1	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
Station 9															
Pull net	0	0	34	-	25	0	0	0	0	0	0	0	0	0	0
0.5 m net	8	<1	5	-	7	1	0	<1	0	0	0	0	0	0	0
1.0 m net	0	0	1	-	0	0	0	0	0	0	0	0	0	0	0
Lake George															
Pull net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	<1	-	0	0	<1	0	0	6	0	0	0	0	0

Table D12. Spatial and temporal occurrence of lake whitefish larvae (No./100 m^3) collected in the St. Marys River, 1981.

Location/Gear	Week 1	2	2	3	5	6	7, 8	10	12	14	16	18	21	23	26
Station 5															
Pull net	12	10	23	167	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	<1	0	0	0	3	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	0	0	-	0	0	0	0	0	0	0	0	0	0
Station 7															
Pull net	0	0	20	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	<1	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
Station 9															
Pull net	0	0	0	-	13	18	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	6	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	<1	-	0	0	0	0	0	0	0	0	0	0	0
Lake George															
Pull net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
0.5 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0
1.0 m net	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0

APPENDIX E. Weekly ranges of physical/chemical parameter measurements taken in the St. Marys River during 1981.

Table E1. Weekly ranges of physical/chemical parameter measurements taken in Course 5, St. Marys River, from 5 April through 5 December, 1981.

Date	Dissolved Oxygen (ppm)	Turbidity (NTU)	pH (S.U.)	Dissolved Solids (ppm)
4/5 - 4/11		2.2 - 6.0	---	---
4/12 - 4/18	13.4 - 13.7	2.0 -10.0	7.0 - 7.2	60 - 65
4/19 - 4/25	13.1	4.0 -15.0	7.1 - 7.4	55 - 65
4/26 - 5/2	12.4 - 13.1	1.1 - 1.6	7.3 - 7.4	61 - 63
5/3 - 5/9	10.3 - 11.6	1.8 - 2.6	7.1 - 7.2	57 - 65
5/10 - 5/16	11.9	0.6 - 2.1	7.2 - 7.4	64 - 67
5/17 - 5/23	11.6 - 12.1	0.8 - 1.1	7.1 - 7.3	59 - 63
5/24 - 5/30	11.4	0.9 - 1.6	7.3	58
5/31 - 6/6	11.2 - 11.3	0.9 - 9.4	7.3	58 - 61
6/7 - 6/13	10.4 - 11.4	1.4 - 2.7	7.3 - 7.4	52 - 58
6/14 - 6/20	10.1	0.7	6.8	55
6/21 - 6/27	10.5	2.3 - 2.5	6.7 - 7.2	56 - 60
6/28 - 7/4	10.0 - 10.3	3.0 - 4.9	7.6	60
7/5 - 7/11	9.9 - 10.8	1.3 - 3.1	6.6 - 7.1	55 - 62
7/12 - 7/18	---	---	---	---
7/19 - 7/25	9.7	1.4 - 2.4	6.9 - 7.6	55 - 57
7/26 - 8/1	9.2 - 9.8	2.4 - 2.8	7.9 - 8.2	57
8/2 - 8/8	9.3 - 9.4	1.4 - 4.0	7.3 - 7.9	53 -150
8/9 - 8/15	3.5 - 9.6	1.3 - 2.3	6.6 - 7.4	51 - 76
8/16 - 8/22	9.9	3.1 - 3.5	7.1 - 7.3	60 - 68
8/23 - 8/29	9.8 - 10.2	1.3 - 2.5	7.1 - 7.2	55 - 61
8/30 - 9/5	11.1	1.5	6.9	63
9/6 - 9/12	9.4 - 10.0	1.6 - 6.4	6.8 - 7.1	55 - 61
9/13 - 9/19	8.2 - 9.8	2.4 - 2.6	6.9 - 7.5	55 - 59
9/20 - 9/26	9.5 - 10.4	2.3 - 2.6	5.4 - 5.9	54 - 60
9/27 - 10/3	8.6	1.5 - 2.5	4.9 - 6.6	55 - 58
10/4 - 10/10	6.6 - 11.4	2.5 - 5.2	6.1 - 6.8	53 - 65

Continued

Table E1. (Concluded)

Date	Dissolved Oxygen (ppm)	Turbidity (NTU)	pH (S.U.)	Dissolved Solids (ppm)
10/11 - 10/17	11.3	4.7	6.6	55
10/18 - 10/24	8.8 - 11.3	2.0 - 18.0	6.3 - 7.2	49 - 142
10/25 - 10/31	11.4 - 12.0	5.4 - 8.5	6.6	62 - 65
11/1 - 11/7	---	---	---	---
11/8 - 11/14	12.6 - 13.0	2.6 - 3.6	6.6	70 - 121
11/15 - 11/21	---	---	---	---
11/22 - 11/28	---	---	---	---
11/29 - 12/5	11.4 - 12.8	1.7 - 3.5	6.3 - 6.4	58 - 61

Table E 2. Weekly ranges of physical/chemical parameter measurements taken in the Middle Neebish Channel, St. Marys River, from 5 April through 21 November, 1981.

Date	Dissolved Oxygen (ppm)	Turbidity (NTU)	pH (S.U.)	Dissolved Solids (ppm)
4/5 - 4/11	11.9 - 13.2	1.6 - 6.7	---	---
4/12 - 4/18	12.0 - 13.9	3.9 - 5.2	7.0 - 7.3	55 - 65
4/19 - 4/25	11.1 - 13.2	1.5 - 2.1	7.2 - 7.3	60 - 62
4/26 - 5/2	13.1 - 13.6	1.0 - 1.1	7.3	64 - 67
5/3 - 5/9	12.9 - 13.0	1.4 - 3.1	7.2 - 7.3	60
5/10 - 5/16	11.1 - 12.1	0.6 - 1.9	7.2 - 7.4	59 - 65
5/17 - 5/23	11.5 - 12.0	0.8 - 2.3	7.3	59 - 65
5/24 - 5/30	11.4	1.1 - 1.3	7.4	56 - 58
5/31 - 6/6	10.0 - 11.7	0.9 - 1.7	7.3	58 - 61
6/7 - 6/13	8.8 - 11.3	1.2 - 1.8	7.3 - 7.4	55 - 59
6/14 - 6/20	9.8 - 10.3	2.0 - 2.5	7.4	55
6/21 - 6/27	9.4 - 10.8	1.7 - 2.5	6.2 - 7.5	51 - 60
6/28 - 7/4	10.1 - 10.6	1.6 - 2.4	7.0 - 7.5	55 - 60
7/5 - 7/11	8.7 - 10.6	1.7 - 3.7	6.7 - 6.9	60 - 70
7/12 - 7/18	8.1 - 9.8	2.0 - 3.7	6.8 - 7.8	51 - 58
7/19 - 7/25	9.4 - 10.1	1.6 - 2.2	6.8 - 7.7	52 - 64
7/26 - 8/1	---	---	---	---
8/2 - 8/8	9.2 - 9.9	2.0 - 6.8	7.6 - 8.2	52 -175
8/9 - 8/15	---	---	---	---
8/16 - 8/22	9.0 - 10.2	2.2 - 3.4	6.7 - 7.3	55 - 61
8/23 - 8/29	9.7 - 10.2	1.4 - 3.8	7.0 - 7.6	52 - 62
8/30 - 9/5	10.5 - 10.6	1.2 - 2.5	7.0 - 7.1	60 - 65
9/6 - 9/12	9.8 - 10.4	1.4 - 2.8	6.9 - 7.1	51 - 58
9/13 - 9/19	9.3 - 9.9	1.8 - 3.1	6.5 - 7.2	50 - 61
9/20 - 9/26	8.8 - 10.5	1.8 - 3.4	6.1 - 7.4	54 - 80
9/27 - 10/3	5.7 - 10.6	2.0 - 7.8	4.8 - 6.5	52 - 60
10/4 - 10/10	---	---	---	---

Continued

Table E2. (Concluded)

Date	Dissolved Oxygen (ppm)	Turbidity (NTU)	pH (S.U.)	Dissolved Solids (ppm)
10/11 - 10/17	9.9 - 11.2	3.5 - 18.0	6.2 - 6.6	52 - 65
10/18 - 10/24	---	---	---	---
10/25 - 10/31	---	---	---	---
11/1 - 11/7	11.4 - 12.6	1.9 - 23.0	6.3 - 7.1	62 -158
11/8 - 11/14	---	---	---	---
11/15 - 11/21	12.0 - 13.5	1.4 - 2.2	6.5 - 6.6	62 - 71

Table E3. Weekly ranges of physical/chemical parameter measurements taken in Lake George, St. Marys River, from 5 April through 5 December, 1981.

Date	Dissolved Oxygen (ppm)	Turbidity (NTU)	pH (S.U.)	Dissolved Solids (ppm)
4/5 - 4/11	12.8	11.0 - 26.0	---	---
4/12 - 4/18	12.4 - 13.7	2.0 - 10.0	7.4 - 7.5	60
4/19 - 4/25	---	---	---	---
4/26 - 5/2	12.6 - 12.8	2.0 - 2.8	7.3 - 7.4	61
5/3 - 5/9	9.5 - 11.7	2.3 - 43.0	7.2 - 7.3	60 - 74
5/10 - 5/16	11.5	3.0 - 9.6	7.3	64 - 65
5/17 - 5/23	11.5 - 12.9	1.8 - 3.3	7.3 - 7.4	59 - 63
5/24 - 5/30	10.8	2.8 - 6.7	7.4 - 7.5	57 - 59
5/31 - 6/6	10.8 - 11.8	1.3 - 1.7	7.3 - 7.4	55 - 59
6/7 - 6/13	8.7 - 10.5	4.5 - 19.0	7.3 - 7.4	51 - 60
6/14 - 6/20	9.9	2.5	6.2	111
6/21 - 6/27	9.9	2.2 - 7.4	6.8 - 7.2	56 - 61
6/28 - 7/4	8.7 - 10.4	2.2 - 5.3	7.4 - 7.8	41 - 65
7/5 - 7/11	9.4 - 10.6	2.8 - 5.5	6.6 - 7.0	56 - 65
7/12 - 7/18	---	---	---	---
7/19 - 7/25	9.2	1.7 -120.0	7.6 - 7.8	56 - 62
7/26 - 8/1	7.0 - 10.1	3.8 - 17.0	7.3 - 7.8	59 - 68
8/2 - 8/8	9.9	1.9 - 90.0	7.5 - 8.4	60 - 63
8/9 - 8/15	6.9 - 9.0	2.7 - 15.0	6.9 - 7.4	65 - 79
8/16 - 8/22	9.1 - 10.5	2.5 - 3.5	7.0 - 7.3	61 - 64
8/23 - 8/29	9.0 - 10.4	1.8 - 13.1	7.1 - 7.8	58 - 62
8/30 - 9/5	6.4 - 9.9	3.6 - 4.6	6.9 - 7.2	61 - 72
9/6 - 9/12	9.1 - 10.8	1.5 - 4.6	6.8 - 7.2	53 - 59
9/13 - 9/19	9.2 - 10.3	12.0 - 43.0	7.0 - 9.2	68 - 69
9/20 - 9/26	9.2 - 10.5	2.0 - 2.7	5.8 - 6.1	62
9/27 - 10/3	10.5	3.5 - 28.0	5.0 - 6.2	58 - 69
10/4 - 10/10	8.7 - 11.6	2.8 - 35.0	6.3 - 6.8	57 - 62

Continued

Table E3. (Concluded)

Date	Dissolved Oxygen (ppm)	Turbidity (NTU)	pH (S.U.)	Dissolved Solids (ppm)
10/11 - 10/17	10.5	2.7	6.9	56
10/18 - 10/24	9.1 - 10.9	3.0 - 3.9	6.8 - 7.2	69 - 70
10/25 - 10/31	11.5 - 12.6	3.2 - 68.0	6.3 - 6.9	22 -112
11/1 - 11/7	---	---	---	---
11/8 - 11/14	12.8 - 13.1	3.4 - 5.0	6.7	132 -138
11/15 - 11/21	---	---	---	---
11/22 - 11/28	---	---	---	---
11/29 - 12/5	13.1 - 13.2	2.2 - 9.7	7.1 - 7.6	53 - 55